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INTEGRATIVE KNOWLEDGE-BASED DESIGN SYSTEMS: A View

1. INTRODUCTION

The IMS Institute is a building research institution with a wide range of activities. In 1987 a small "Design Research Workshop" was organized to study the impact of computers technology on the architectural design process methodology in general, and on design, manufacture and assembly of the Institute's "IMS Building System" in particular. The system consists of a prestressed concrete skeleton structure and various sub-systems, and has been applied extensively in housing and public building.

The research content was chosen for the practical reasons: the IMS design methodology was sufficiently defined, and the project results were expected to help the novice IMS designers and serve as a teaching medium at the Faculty of Architecture of the University of Belgrade, where the IMS System is the subject in the 3rd Year construction course. In the period 1987-88 all programs were made "from the start".

The paper describes a part of the workshop research results, and presents some ideas on an on-going attempt to make an "integrative" knowledge-based design system.

2. PROTOTYPES DEVELOPMENT

The work of the group has been following two parallel tracks: a) development of prototypes of design "assistants" or "consultants" in the early stages of the design process, and b) development of prototypes of "shells" which could be used for making "small" expert systems to complement the design process.

2.1 GIMS-EXPERT

GIMS-EXPERT is a consultant to a designer of individual family houses to be built in the "IMS building system, in this instance featuring the modular structural skeleton grid of 4,20 x 4,20 m. Following the user's preference of the shape of the house, type and number of functional spaces and the location data, the expert generates a set of feasible house designs on the sketch design level, using the elements from the GIMS Catalogues and rules on their combinations. The catalogues include the "functional elements" which are the alternative functional entities (such as living rooms, entrance-stairs-WC-or-bathroom units, bedrooms with corridor etc., all designed to fit the structural module. The ground-floor and first- floor plans are generated separately, and then fit together. The "Roof Generator" makes all possible roof combinations using the Roofs Catalogue.

The sketches are subsequently evaluated and sorted out according to the heuristics rules on the relation between indoor spaces and outdoor specific micro-climate conditions, vistas etc. Each alternative is supported by the explanation of the expert's (changeable) evaluation method. For each alternative, ground-floor and first-floor plans, isometric or perspective surface-model views of the house with all possible roof solutions are presented on the screen and offered to be drawn on the plotter. By the additional geometric transformations, the town-planning structure elements (i.e. rows of houses) are composed from the individual houses by the interactive mode of work. In 1987, an operative prototype version was made for DEC MicroVAX II computer (Petrovic et al. 1987). In 1990, the program was embedded into the Autodesk Ltd. package AutoCAD Release 10, which served as the symbolic/graphic environment on the PC XT-AT computers.

When asked to demonstrate the possibility of application of GIMS-EXPERT prototype to a real-life problem to "prove that research leads to practical results", we were able to produce a fair choice of designs of IMS houses in various alternatives and presentations very quickly. The most interesting part of the program (to us) seemed to be the roof generator, which produces some quite "unexpected" results, "which the designer would have certainly made had he had the time". However, the idea that the program serves as a "silent partner" while the designer is doing "more important jobs" did not appeal to the fellow architects who showed little enthusiasm to use it. On the other hand, various building entrepreneurs were of a different opinion, wanting to use the program as an "automatic designer". Inasmuch the program prototype appears to "work", the number of design criteria is small, and the knowledge-base has not been the fully completed. Such problems, of the completely different nature from the research ones, are nevertheless real and ask for the due attention.

2.2 Generators of House Plans
In order to improve the existing plan generator of GIMS-EXPERT, other "exhaustive" plan generators with rectangular shapes of different sizes were explored. One of them was FLOP-1, using Per Galle's algorithm (Galle 1981). It was an improvement, but the incorporation into the existing GIMS-EXPERT was not made (Svetel 1989).

2.3 Expert Systems Shells
In the period 1987-89, various shell prototypes were made for both MicroVAX and PC computers. They all have the features similar to those of the existing low price bracket commercial shells, and do not deal with uncertainties as yet.

The shell "MARIA" is a forward/backward rules chaining mechanism. As for now, it uses the commands such as: list facts, list rules, prove, infer, explain, etc., can call an external program and has the editing facilities (Cubric et al. 1988). Application is on MicroVAX and PC computers. The initial (successful) testing was made by the application of a part of the House-Building Regulations dealing with the Fire Codes.

The development of shells brought some interesting points into focus. For example, the "filling" the shell with knowledge appeared to be a problem. It was quite difficult to persuade an expert to take part in the project. The existence of a knowledge engineer become critical as the structuring of knowledge proved to be very important for our types of shells,

and not a simple task to the persons who know little about the principles involved. The best solution we see here is in joining forces of a practice (such as ours) and academy. The motivated MSc and PhD students are probably the best developers of single, "modular" programs of the types we describe here.

It was very comfortable to be able to change the source code adapting the method to the problem and not vice-versa, and extend the programs into any desired direction. However, transforming them into the commercial applications was a completely new problem. Obviously, our prototypes could be developed into the complete error-free packages should the need arise, but who in principle should be developing such programs remains to be decided on.

3. DESTOOLS: A SET OF DESIGNER'S CAAD TOOLS

3.1 Introduction

In view of the obtained results and gained experience, in 1990 we decided to "pull all things together" and investigate the possibility of making a fully integrated design knowledge-based system. For the time being, we are making a feasibility study to decide on the possible ways of doing it. For the start, we decided to make a "a weak structural frame", with a set of designer's CAAD tools where a designer would be able to choose and apply the method appropriate to the problem at hand. It is expected that this structure would be relatively easy to change, and adapt to the particular circumstances. It will relate to the selected domain of GIMS housing design, and be applicable be applicable on the PC computers.

3.2 The Structure

To conceptualize the frame, firstly we had to go back to the description of the part of design process we wanted to model. A well-known selected design sequence consists of: a) problem definition, b) synthesis of possible solutions and c) evaluation and selection of the proposed solution. These sequences shall be supported by the separate program modules: a) the interface (where the problem is defined), b) the generator of feasible solutions, and c) the evaluator and selector of the best one solution a set of the acceptable ones. GIMS-EXPERT fits into category b) while the shells come into the category c).

The problem definition is a very important phase as it defines the nature of the design problem, and explains to the designer the limits of his efforts. However, this module still awaits further elaboration; for now, it is a simple interface by which the user inputs the initial data.

The synthesis, or generation of the possible solutions depends on the problem type: if the problem is deterministic, then the "synthesis" of the solutions is more or less straightforward, allowing the application of various algorithmic techniques, and "optimization" of results in the true sense of the word. If the design problem is probabilistic, and most architectural problems are of this kind, then one can only talk of the "satisficing" solutions, where the best one is selected by heuristic methods (Simon 1969). However, inasmuch a designer may (or should) know that the solution he proposes is not "ideal", very often he is impelled to accept it either by his will (in case of "normative" design) or in light of the real-world circumstances, and treat the probabilistic facts "as if being deterministic".

Deterministic problems need no further evaluation unless some criteria were left out in the generation process for the simplicity sake. For example, GIMS-EXPERT includes a generate-and-test mechanism where the rough evaluation is made, while the finer evaluation is done subsequently. The proportion of constraints between those that generate the solutions and those that test them, is a delicate, heuristic matter. Too many design criteria may lead to very complex programs containing perhaps not so important design aspects. Therefore we propose to make a separate "evaluator" for both determinist and probabilistic design problems, and use various evaluation tools separately. For example, we might like to select from the set of proposed GIMS design solutions only those which comply with some well-defined and structured seismic conditions in a certain region. In this case we shall apply the specific tool of algorithmic nature. However, if we want instead to select such houses that have roofs which "fit" into the built and natural surroundings, we need an experts opinion of a different nature. Both problems could be solved by one, more general and more complex system, but could be solved by separate and simpler, "problem oriented" systems as well. We are now experimenting with the latter kind. As far as the multi-level decision making is concerned, although it is in principle possible to teach the machine to reason on various meta-levels, at present we would rather leave to the designer to do so.

To use only the "critical" criteria, which might be different in various design situations, my be a risky proposal to a novice. Which are the "critical design decisions" is left to the expert to decide. In fact, many an expert applies only the independant critical examinations of the problem on the conceptual level of design anyhow, being able to judge the appropriateness and consequences of each applied evaluation criterion, and devise a plan for further prototype transformation upon such "partial" results. In some sense, this approach simplifies the matters what is appealing at first. However, as Sir Karl Popper once said, "seek simplicity but do not trust it", we are nevertheless aware of the risk that the reduced number of design decision taken on this level may leave out some really important ones. But, this would be due to human, not machine error. Also, we do not exclude the possibility that the results of such partial design efforts affordable by DESTOOLS could enable the creative designer to "sniff out" an entirely novel design solution which, until then, might had been hidden behind the hill.

3.3 The Problems

Inasmuch this simplified loose model treats only a selection of the most frequent design decisions, many problems of DESTOOLS design and implementation are the same as if it were a complex design system dealing with the proper blackboard organization etc. (Pohl 1989). Examples of such problems relate to the knowledge representation types and the knowledge base organization.

In all programs so far, we have applied the rule production systems, combined with the logical IF-AND-OR trees for evaluation of solutions. We have started to experiment with frame representations, combining them with rules (Fazio et al. 1989). We are aware of the importance of the definition of the product model standard which is actually the meeting point of all our modules (Bjork 1990). At present, we prefer small (independent) knowledge bases instead of the large, all-embracing ones, because of the better control and

easier change and extention of the former. This may be only a temporary decision due to the nature of used hardware and software, and is awaiting for further elaboration.

The most pressing problems awaiting are those of interface development, multiple types criteria handling, selection of symbolic/graphics environment, and naturally, the selection of the type of design decision making. For the time being, we are staying in the PC computer domain as is the majority of the would-be users of our programs.
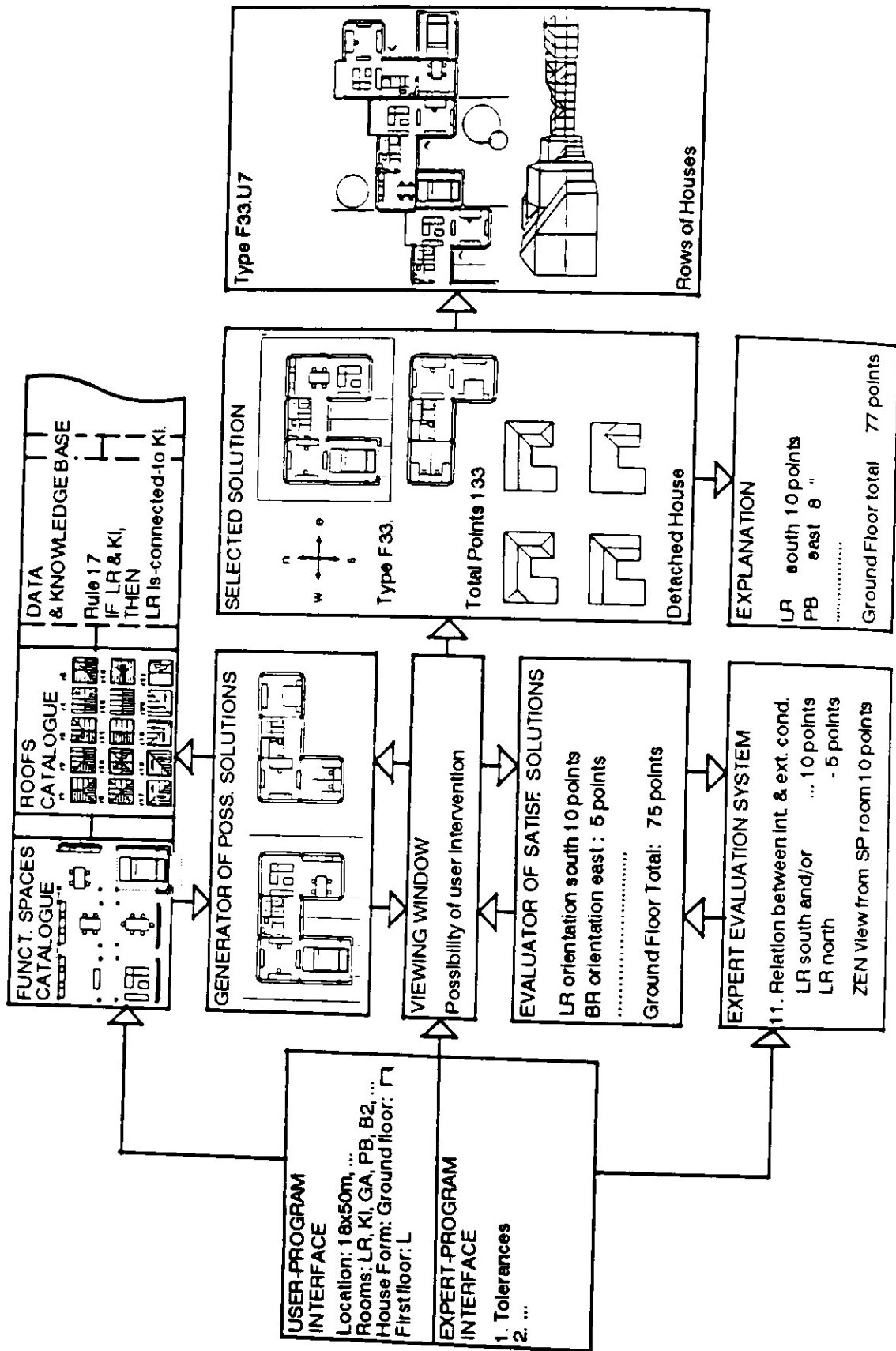
How much such packages should be integrated, depends on the circumstances. The integration of modules that deal with the conceptual phases of design process is still a great problem for AI methodology and could be done only in the great centers of learning. Integration of many tasks in the detailed design phase has already been realized in large building firms and architects practices.

4. CONCLUSIONS

The most important benefit from the first phase of our project might have been in the elaboration and definition of the design process, rather then in the applicability of the results. Also, we are now aware of many more problems related to the development of knowledge-based design systems , than we were at the beginning. These might prove to be very useful and important factors in planning the next phases of our research.

5. REFERENCES

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Type F33.U7

Rows of Houses

FUNCT. SPACES CATALOGUE

ROOFS CATALOGUE

DATA & KNOWLEDGE BASE

Rule 17
IF LR & KI,
THEN
LR is-connected-to KI.

GENERATOR OF POSS. SOLUTIONS

SELECTED SOLUTION

N
W — E
S

Type F33.

Total Points 133

Detached House

VIEWING WINDOW

Possibility of user intervention

EVALUATOR OF SATISF. SOLUTIONS

LR orientation south 10 points
BR orientation east : 5 points
....
Ground Floor Total: 75 points

EXPLANATION

LR   south 10 points
PB   east 8 "
....
Ground Floor total   77 points

EXPERT EVALUATION SYSTEM

11. Relation between int. & ext. cond.
    LR south and/or   ...10 points
    LR north   - 5 points
....
ZEN view from SP room 10 points

USER-PROGRAM INTERFACE

Location: 18x50m, ...
Rooms: LR, KI, GA, PB, B2, ...
House Form: Ground floor:
First floor: L

EXPERT-PROGRAM INTERFACE

1. Tolerances
2. ...

DIAGRAMMATIC PRESENTATION OF GIMS-EXPERT PERFORMANCE