Three Applications of BATI-SHELL, a Shell for Expert Systems Creation

Trois applications de BATI-SHELL, un shell pour la création de systémes experts

Drei Anwendungen von BATI-SHELL, einer Shell zum Aufbau von Expertensystemen

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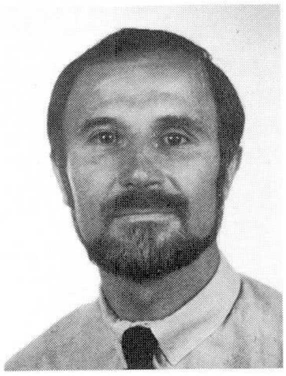

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SUMMARY
BATI-SHELL is a tool which is particularly well suited to the realization of expert systems in the field of construction with a hierarchical structure of the base entities. It is a result of our experience in the realization of three expert-systems:
— CESSOL, whose objective is to contribute to the specification of soil investigations.
— ADOCC, which is able to analyze and describe the framework of current constructions.
— DESCARTES, connected with a CAD system, whose aim is to deduce the material characteristics for each kind of structure element in a building.

RESUME
BATI-SHELL est un outil bien adapté à la réalisation de systèmes experts dans le domaine de la construction avec structure d'entitès de base du type hiérarchique, il est le résultat de notre expérience dans l'élaboration de trois systèmes experts:
— CESSOL, dont l'objectif est de contribuer à la spécification de campagnes de reconnaissance de sol.
— ADOCC, qui est capable d'analyser de décrire la structure de construction.
— DESCARTES, couplé à un système de CAO, dont l'objet est la déduction des caractéristiques des matériaux constituant chaque sorte d'ouvrage dans un bâtiment.

ZUSAMMENFASSUNG
BATI-SHELL ist ein Werkzeug, das für die Verwirklichung von Expertensystemen im Bauwesen sehr geeignet ist. Es ist das Ergebnis unserer Erfahrungen bei der Realisierung von drei Expertensystemen. Ihre Datenbasen sind hierarchisch angeordnet:
— CESSOL, zur Festlegung der Baugrundwerte.
— ADOCC, um Gebäudestrukturen zu analysieren und zu beschreiben.
— DESCARTES, (mit einem CAD-System zusammenarbeitend) zur Bestimmung der Charakteristiken der Baumaterialien aller Gebäudeelemente.

1. INTRODUCTION

To develop various applications in building and construction field, we have created a shell dedicated to expert systems generation for computer aided design. Using our experience acquired during the development of the CESSOL and ADOCC expert systems, we can deduce that there is a class of problems leading to the same kind and the same structure of systems. This fact has been confirmed while we elaborated the third system (DESCARTES) presented in this paper.
After a short presentation of each expert system, through some explanations about the objectives, the structure of data, the nature of results and the reasoning process we will make a synthesis about the common characteristics of these expert systems and finally we will describe the composition of BATI-SHELL.

2. THE EXPERT SYSTEM CESSOL

2.1 Goals

CESSOL [1][2][3][4] is an expert system for the design of geotechnical site investigations for buildings.
A campaign of geotechnical site investigations is a set of tests made in a ground, in order to get all the information which is necessary to define the foundation conditions of a building on this ground.
CESSOL has to simulate the reasoning of an expert placed in two distinguished situations :
- the expert has to design a campaign of geotechnical site investigations to resolve a given problem : that is the case in a consultancy or in a geotechnical company for an engineer who has to propose a single campaign of geotechnical site investigations, the best one according to the problem to be studied and the characteristics of the company.
- the expert has to analyze a given campaign of geotechnical site investigations in order to know if it is suitable for the problem : that is the case for a consultant-engeneer working for an architect or a promoter, and who examines the answers at a bidding procedure in order to judge whether they can solve the given problem, and to choose the best one.
In this second situation, the expert must be able to consider all the possible solutions and not only one of them such as in the first situation.

2.2 Nature and structure of the data base

The campaign of geotechnical site investigations is defined from various data concerning:
- the building : information related to its purpose (dwelling, factory, offices, hospital, ...), its dimensions, its structure, etc.; this information can be known or unknown, more or less precisely ;
- the ground : it is characterized by its topography (size, slope) and its internal structure, such as the nature and the geometry of the layers, the existence of groundwater or cavities and the mechanical properties of the constituting elements.
This data constitutes a hierarchical data base that can be represented by subtrees. Each subtree is associated with a kind of main concept (building, soil ...)

2.3 Reasoning process

According to the expert's way of reasoning, the inference engine works according to the following sequence :

- data completion :
whose goal is to complete the data of the problem, from the answers given by the user;
- activation of the objectives :
a sub-set of suitable rules, applied to the data of the problem to be solved, define the objectives (bearing capacity, settlements, stability, ...) which have to be activated ; saying that an objective has been activated, means that the campaign of geotechnical site investigations has to procure all the necessary information for calculating and reasoning about the corresponding aspects of the problem;
- geotechnical investigation depths :
an algorithmic module is then needed to determine the investigation depth for each objective, that is to say the depth to which the necessary tests will be conducted in order to answer distinctly the questions of each objective;
- set of the necessary possible tests :
the following phase consists in elaborating the set of the necessary possible tests to answer the activated objectives. The inference engine then develops an AND/OR arborescence, by replacing each objective by successive sub-objectives, then by tests, objective by objective and layer by layer, for all the layers met on the depth of investigation of a given objective.

The result of this work is a set of tests which indicates, for each objective and for each layer concerned, the set of tests which allow this objective to be satisfied, these tests being linked by "AND" or "OR" whether they are simulateneously necessary or interchangeable.

3. THE EXPERT SYSTEM ADOCC

3.1 Goals

ADOCC [5] is an expert system for the analysis and the description of the frameworks of current constructions (wooden frames, roofing supports, building shell infrastructure, superstructure work and foundations).

The aim of the expert system ADOCC is to establish descriptive explanatory notes for centres of interest (frame, building shell, foundations). We are attempting to obtain a qualitative description of the works in such a way that they are consistant with the two others.
For each of the centres of interest the system will provide, as a definitive document, a qualitative description of the work split up into a certain number of elements (concrete, steel, shutterings, facing, mixings...) . The result provides us with an intermediate stage which is the production of a set of sheets describing the work, on the basis of which the description will be made.

3.2 Nature and structure of the data base

The starting data and the facts are of two sorts :
- the principal information describing the project (building, ground, site environment and appearance) the answers to the corresponding questions are not obligatory ; values by default can be taken : the range of possible answers is proposed to the user;
- the geometric data obtained from the basis of available graphic documents. They constitute the support from which certain representative values are extracted.

All those data are introduced into the system answering a single questionnaire. The questionnaire is organised in subtrees concerning the building, the ground , the site, the environment and the appearance.

3.3. Reasoning process

The way of reasoning of the expert is structured according to the principal technical functions of the building's elements. We can define three macro-functions which can be split up into a certain numbers of functions and sub-functions
The MACRO-FONCTIONS are : SEPARATION - SUPPORT - COVERING

ADOCC uses sets of rules allowing the structure of the building to be analysed and rules to put the descriptive into shape. At the end of the process ADOCC can give explanations about the reasonings carried out , as well as justification for the absence of certain solutions.

4. THE EXPERT SYSTEM DESCARTES

4.1 Goals

To realise technical and economic evaluations during the pre-project phase we have elaborated a CAD system named X2A [6].In this system , like in many other CAD systems, the definition of the project is elaborated in two stages :
- the definition of the "wireframe" , based on geometrical facets decomposition. A facet is a horizontal or vertical plan, whithout thickness. It separates the various volumes that constitute the building.
- the differenciated covering by addition of elements into a catalogue. This operation consists of associating a technological component with each facet.

This second phase interests us in order to bring facility and time saving to the designer. Three levels of action could be envisaged to do this:
- the use of graphic editors for facets generation and elements connection ;
- the definition and the utilisation of commands of the covering allowing the designer to add an element to a set of geometric facets identified by a function;
- the deduction of technical solutions on the basis of choices.

This third point about technical solutions deduction is the main objective of DESCARTES[7] .

4.2 Nature and structure of the data base

The initial facts on which the reasoning is based are of two types :
- the descriptive data of the builiding located in the Data Base of X2A ;
- the choices and the constraints of the designer. This information represents the technical orientations intended by the designer. It is independent of the geometrical data and results from a decision taken by the designer.

The results of reasoning are the components characteristics that must verify the designer choices.
The whole data is connected in a single tree that puts together the building characteristics, the different parts of building, the associate components and their characteristics.

4.3 Reasoning process

The first stage consists of defining for each type of domain to be covered the type or the types of material compatible with the domain in such a way that there is coherence between the different technical solutions in the building. A domain is a set of facets answering a same function : floorboards, supports, cell separators, ...).

The second stage consists of defining the characteristics of the materials to be implemented to assure the desired performances. These characteristics are represented by a set of values (nature of the material, minimum thickness, mass, thermal coefficients) for each layer of a same component (wall, floor), according to its localisation, the functions it has to assume and the constraints imposed by the designer. The set of characteristics is the result of the expert system DESCARTES.
From this data it is possible to find in a data base the material or materials that verify the deduced demands, and to set up the different layers of the corresponding component. Then we could elaborate the covering commands that can be automatically exploited by the CAD system X2A.

5 SYNTHESIS : COMMON CHARACTERISTICS OF THE THREE EXPERT SYSTEMS

Despite the different purposes and goals of the three expert systems we can consider that they constitute a kind of family identified by a set of common characteristics.

5.1 Hierarchical structure of data

Like in many problems we found in the construction field, it is easy to represent the data set by a tree

5.2 Questionnaire to define a particular problem

To define its problem, a user must fill in (even partially) the tree, answering a questionnaire. This questionnaire may be automatically elaborated from the hierarchical structure of data.

5.3 Rules for data completion

For each expert system it is necessary to write a set of rules whose aim is to complete the data tree, exploiting knowledge about the data base. We can notice that this step is typically the way of working for the expert system DESCARTES.

5.4 Dynamic construction of AND/OR trees

For the CESSOL and ADOCC expert systems, the problem solution could be represented by an AND/OR tree. In this expert systems we found a set of rules whose aim is to construct the solution from the data base.

5.5 Explanation

For the designer it is very interesting to have a tool that can allow the solutions to be verified. In particular if it gives the answer to the questions " why ?" and " why not ?".

6. BATI-SHELL [8]

6.1 The utilization context and results of BATI-shell

It is important to distinguish the user of the shell, whose knowledge is used to construct an expert system, and the user of the expert system himself. They are respectively called the "expert" and the "user" (Fig. 1).

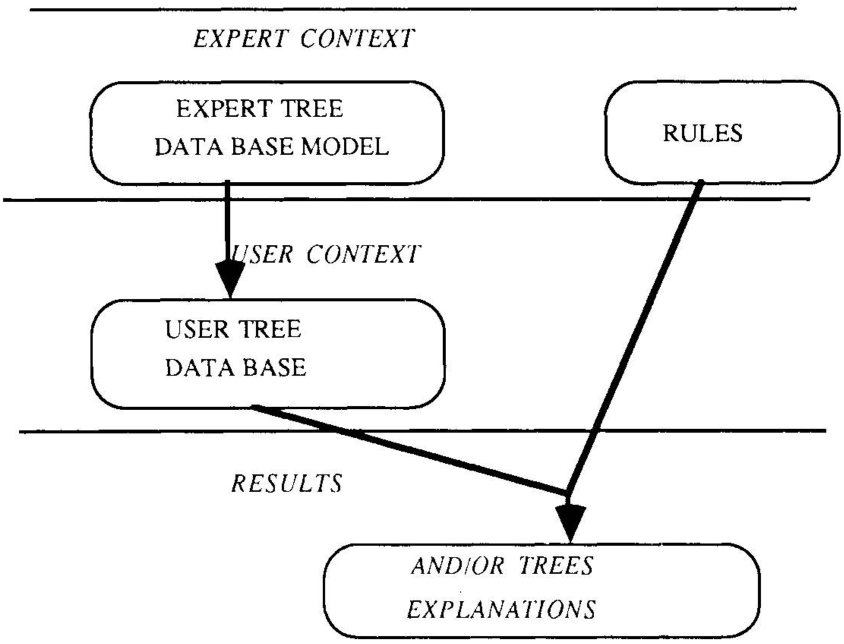

Fig. 1 The expert and user contexts

The expert has to provide the knowledge required for the construction of the expert system, that is to say a model for the data base and a set of rules.

Before defining the rules, the expert has to structure concepts that are necessary for describing the problems which belong to the same class. This structure becomes a model for the data base. The structure leads to a hierarchical relation between the concepts that is represented by a tree called the expert tree.

The system uses the information contained in the expert tree in order to construct a questionnaire that will be answered by the user. It is intended to acquire the data base of a particular problem. This data base is stored in a data structure called user tree.

We can distinguish in these trees, the terminal concepts (the leaves) and the non terminal concepts (the nodes).

The terminal concepts (in the user tree) are the only ones to which it is possible to associate values or sets of values. These values can be obtained from the user's answers to the questionnaire. In this case the expert has to define the concept as "to-be-asked" by the means of an attribute. Furthermore, the expert can define a condition under which the value will be asked to the user.

In addition to this, a sub-set of rules is intended to input or to modify the values of a terminal concept (see below). In this case the concept is "deductible". This possibility is very powerful because it is a means for eventual completion or modification of a partially defined data base.

The non terminal concepts represent more generic entities which can have many instances in the user tree. The rules' variables will refer to the non terminal concepts. For this reasons we will have variables which are typed ones.

Once the expert tree is defined, the expert can specify the rules. The rules will have to make reference to the concepts defined in the tree. The rules are divided in four sub-sets, each one intended to a particular objective.

The first sub-set is destinated to completing and to modifying the data base. For example this rule (in ADOCC)

If (Building destination) = (Level destination)
Then (Level framework) <-- (Building framework)

means that if the building's destination and the level's destination are the same then the value associated with the level's framework will get the value associated with the building's framework. Note that "Building" and "Level" represent variables that will refer to non terminal concepts in the user tree.

The other sub-sets of rules are dedicated to the construction of AND/OR trees which represent solutions (decompositions) of some problems (objectives).

The second one allows the problems to be selected that will have to be solved or studied by means of activation of objectives. For example (in CESSOL):

If (Excavation Stability) = wished
If (Lower Limit's Depth (layer n-1)) < Basement Height
If (Basement Height) > 6m
If (Lower Limit's Depth (layer n)) <= Lower Limit's Depth (layer f)
Then (Objective PASSIVE/ACTIVE Earth Pressure (layer n)) <- active
where layer n is the current layer and f the layer containing the fonudation.

The third sub-set of rules is used in order to construct the solution trees. The rules allow the problems to be split up into a set of sub-problems. The application of these rules leads to AND/OR trees.

Finally, the aim of the last sub-set is to cut off from the AND/OR trees the branches corresponding to inadequate or impossible solution aspects. A track of the application of these rules is stored in order to allow negative explanations to be produced. For example (in CESSOL) :

If (Ground nature) = gravel
Then (Static Penetrometer) <-- prohibited

Once the four sub-sets of rules have been applied, the system's interfaces give, for each problem all the possible solutions. They can also explain the behaviour of system, answering questions like "why ?" and "why not?".

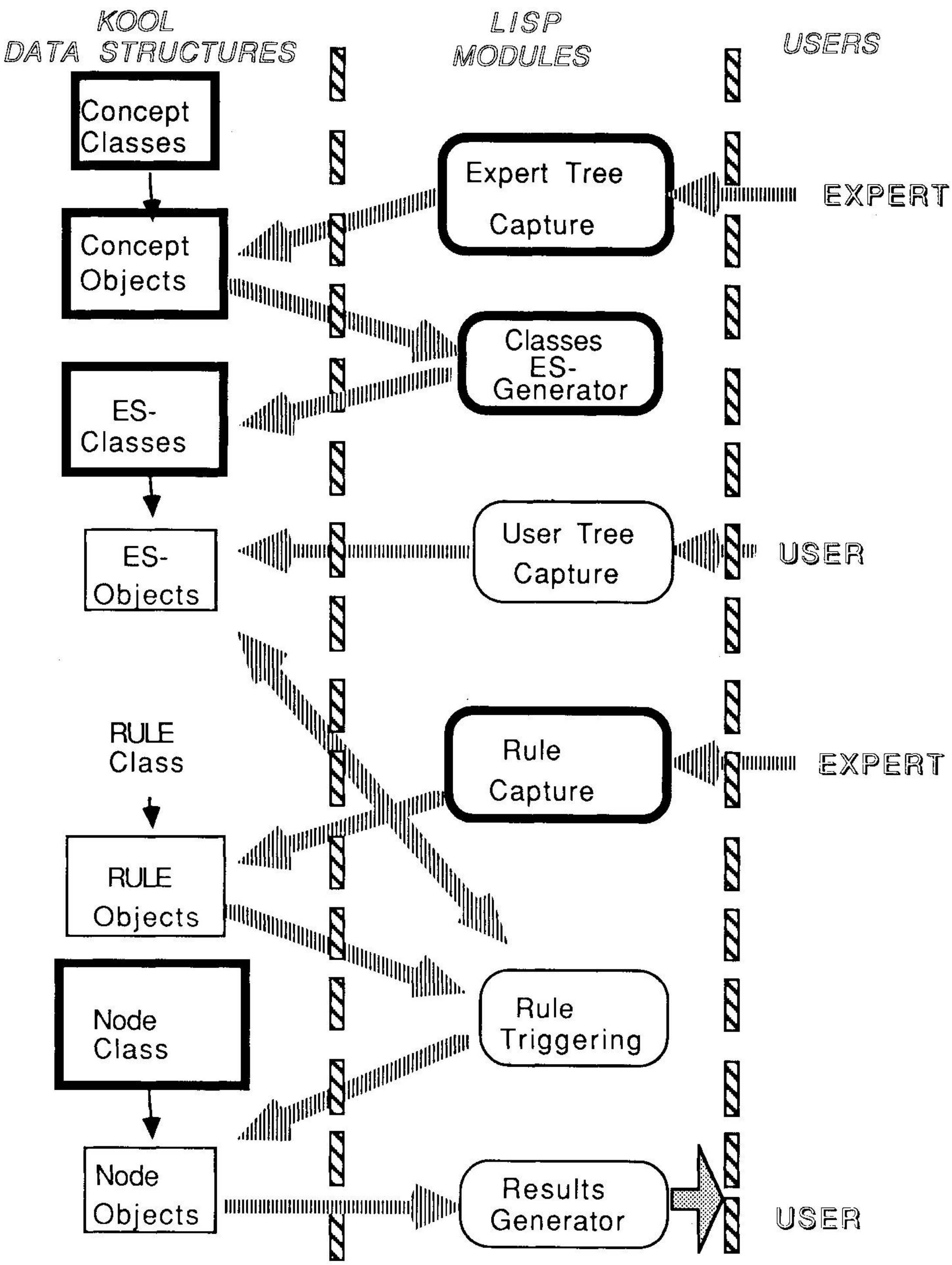

Fig. 2 Architecture of BATI-shell

6.2 Structure of the shell

BATI-shell is developed in KOOL, BULL company's development environment for expert systems construction. It consists on an object language and a inference engine of order one.

The shell contains a set of KOOL objects and LISP modules the function of wich is essentially to interface the users and the KOOL objects. The objects can exist initially or can be created dynamically during the system's working. The figure number 2 shows the relationship between the different KOOL data structures, the LISP modules and the users.

The concept classes define the classes initially know by the system. They represent the terminal and the non terminal concepts. The Expert Tree Capture and the ES-classes Generator modules allow classes to be created, that represent the current data base model. Using the ES-classes and the user's answers, the User Tree Capture module creates the ES-objects which represent the data base. The aim of the Rule Triggering module is to control the application of rules. The condition parts of the rules refer to ES-objects; at the opposite the action part refers to ES-objects (to complete the data base) or to Node Objects (to construct the AND/OR trees).

7 CONCLUSION

Using BATI-SHELL for the expert system DESCARTES development confirmed how it is easy to elaborate such systems in the field of construction when the analysis of the problem is well done. Effectively, the tutoring period needed by the experts of the domain (not specialized in computer sciences) to know how to use BATI-SHELL take only a few days. After this stage, the experts did not need the help of BATI-SHELL authors. They alone defined the base of facts model, constituted the different rules and obtained the first version of the expert system they expected.
At the present time, this shell seems to be a good way to generate a first version of expert systems. Despite the performances level of the result, mainly due to the environment of development (KOOL), that is not yet optimized.
In the field of construction it is current to find a hierarchical structure of data. However, for anyone who wants to elaborate a prototype of expert system, a shell like BATI-SHELL gives a friendly, easy way to obtain a quick answer.

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