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Test Selection for in-Situ Testing by Expert System

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ABSTRACT: In many cases ground assessment by in-situ field-testing is an important aspect. Designer for the proper design; needs many soil parameters. Since there are many methods to compute soil parameters, based on site condition; an experienced engineer or geotechnical engineer is required to select appropriate methods. In this context, an expert system will be of great use to aid in selection of suitable tests for in-situ testing for a particular site condition. In this paper an intelligent; front-end expert system (TSES), that has been developed to select suitable in-situ testing for Indian condition. Like human consultant, the system asks for detailed information regarding the project site such as location, type of project and data available. It then suggests a recommendation based on the information and the systems own knowledge. The developed expert system would be of much potential use in geotechnical engineering and particularly for developing country like India.

I. INTRODUCTION

Expert systems have been used for several purposes. Expert systems are a class of programs that excel in domains where judgment, expertise, and rules of thumb are the predominant part of the knowledge used in solving the problems (Chouicha and Siller 1994). Expert systems manipulate knowledge while conventional programs manipulate data. The adage does not apply to artificial expertise. Once it is acquired, it is around forever, barring catastrophic accidents related to memory storage. Applications of this technology to civil engineering have been discussed by Kostem and Maher (1986). It has also been successfully used in mainly fields, including Civil Engineering in the area of water management and crop management etc. It has great potential in geo-technical engineering also. Till today very few researchers have tried in this field. No such commercial package is available for Geo-Technical Engineer. Some applications related to geotechnical engineering have been described by Moula, Toll and Vaptismas (1995), but there has been limited application of expert systems in geotechnical engineering till date. Lack of expertise with understanding of expert systems among geotechnical engineers, together with suspicion about the usefulness of these systems; have hindered the adoption of the technology.

Sometimes expert has failed to suggest the correct testing method for the site where as an expert system has been proved to be efficient in advising the correct method. It is a very important aspect as improper selection of testing method may lead to erroneous soil parameters. The shell used is 'VIDWAN' (Sasikumar 1999). In the beginning, the architecture and some details of the expert system (ES) shell is explained; followed by description of rule-based expert system 'VIDWAN' and its components, necessity in geotechnical engineering. A knowledge-based expert system has been developed which can assist with processing the raw information of the site for the proper selection of field testing equipment. It can support an experienced geotechnical specialist in the final selection of the proper equipment. The decisions are made by the user with the support of the enhanced knowledge and data processing abilities which the system can provide.

II. ARCHITECTURE OF EXPERT SYSTEM

Internally, an ideal Expert System can be characterized as:

- Extensive specific knowledge from the domain of interest
- Application of search techniques
- Support for heuristic analysis
- Capacity to infer new knowledge from existing one
- Symbolic processing
- An ability to explain its own reasoning

Expert Systems use a wide variety of specific system architectures, primarily because; one architecture will be more applicable than other for a given application. The common architecture is as shown in Figure 1.

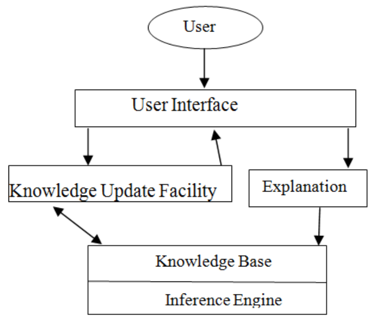

Fig. 1. Expert System Architecture

III. THE TASK OF BUILDING AN EXPERT SYSTEM INVOLVES

Knowledge Based Expert System in Soil Characterization

The knowledge base in an expert system contains facts (data) and rules (or other representations) that use those facts as the basis for decision making. It represents a storehouse of the knowledge primitives (i.e. basic facts, procedural rules, and heuristics) available to the system. The knowledge stored in the base establishes the system's capability to act as an expert. This involves collecting and organizing the knowledge of a particular subject domain, e.g. classification of the soil according to soil physical properties. This procedure involves an expert in the subject of geotechnical engineering; commonly called a domain expert, and an expert in expert system technology, commonly called a knowledge engineer. The three most common ways to represent the knowledge are IF-THEN production rules, frames, and semantic networks.

An expert system is organized as sets of rules, and then it can easily look at the inference chains, it produces to reach a conclusion. Self-knowledge is important in an expert system because

- User tends to have more faith in the results and more confidence in the system.
- System development is faster since the system is easier to debug.
- The assumptions underlying the system's operation are made explicit rather than being implicit.
- It's easier to predict and test the effect of change on the system operation.

The knowledge base stores the knowledge about a subject domain in the form of rules, procedures, tables and comments. The fact base stores the following:

a) The information, the program should ask for in order to carry out the consultation.
b) The specified problems, which are in the form of problem fact Statements, e.g. "the soil type is?" and problem value statements, e.g. "assign the value of Liquid Limit of the soil?"
c) The input facts given by the user, which describe a particular problem. There are two types of input fact: Fact Statements, e.g. "the sand contains clay fines " and Value Statements, e.g. "percentage of sand =62.5%",
d) The various possible conclusions of the consultations may be drawn, which are in the form of Fact Statements and Value Statements.

IV. INFERENCE ENGINE

Expert system, by their nature, deals flexibly with varying situations. The capability to respond to varying situations depends on an ability to infer new knowledge from existing knowledge. The inference engine is a software system that locates knowledge and infers new knowledge from the base knowledge. Inference is the process of making use of known information in order to reach new conclusions. An inference engine consists of search and reasoning methods that enable the system to find solutions. The inference engine contains an interpreter that decides how to apply the rules to infer new knowledge and a scheduler that decides the order in which the rules should be applied. Inference is the process of making use of known information in order to reach new conclusions. The construction of the inference engine is based on the backward chaining reasoning. Since there is no procedure stored that defines how the problem will be solved, there should be at least one reasoning strategy for using the knowledge and solving the problem. A problem can be presented to the system to solve, and this is called a consultation. The inference engine will find a Fact statement, which can be a solution to the Problem Fact Statement (e.g. "the soil is classified CI" is a possible solution of "the soil is classified as?"). It will try to prove the conditions that establish the trueness of that Fact Statement (specifically called the Goal

Statement). Usually the solution to a specified problem is termed as the goal and more than one problem can be specified in each consultation. After a problem has been specified, the expert system applies its internal knowledge to find the solution to that problem.

User Interface Facility

The user interface provides the needed facilities for the user to communicate with the system and is screen-driven. Normally, a user will like to have a consultation with the system, with a view to

- Get remedies for the problem,
- Know the private knowledge (Heuristics) of the system, and
- Get some explanation for specific queries

A data sheet entry form is used for input and output with functions to invoke the explanation facility. Facilities are provided for the user to input knowledge about a subject domain, information or facts about a particular problem, which is within the subject domain and is stored in the knowledge base, and to query the system as to why certain information was necessary or how a certain conclusion was reached. Therefore, the user runs the expert system interactively, for e.g. 'The soil type is '. A good user interface can make an expert system user-friendly and the knowledge base more transparent to the user. The user interface facility must accept information from the user and translate it into a form acceptable to the remainder of the system or accept information from the system and convert it to a form that can be understood by the user

Explanation Facility

Beyond reaching a conclusion when faced with a complex problem, an expert is also capable of explaining, to some extent, the reasoning that led to the conclusion, as expert should have such similar capability. The SCHAR keeps a record of the knowledge that is used in processing, based on the representation scheme of the knowledge base and translate it in to a form that is palatable to the user.

Knowledge Update

The knowledge in many complex domains is constantly expanding and changing; and the knowledge base must be modified correspondingly. The knowledge update facility is used to perform such update.

Rules-Based Expert Systems

The main feature of rule-based expert systems is that the knowledge is represented mainly in the form of productions rules, and this is the most common formalism for representing knowledge. Each rule defines a small, but relatively independent, piece of knowledge, and a set of rules define logical relationships between pieces of knowledge of the subject domain. An example of a production rule is given below (Wong, Poulos and Thorne 1989). rule s1 if Soil dry strength is more than The soil may be clay.

Every rule is given a rule number or a name ("rule s1" in the above example) for identification purpose. There are two base clauses of every production rule:

1. The IF, or antecedent, part of a production rule begins with "if" and specifies at least one condition or more than one conditions.
2. The THEN, or consequent, part of production rule begins with "then".

The THEN part consists of actions or facts based on IF or antecedent part. When the conditions in the IF part are satisfied the actions in the THEN part will be carried out or the facts will be proved to be true.

The advantages of using production rules to represent knowledge in expert systems are:

1) Compared to other knowledge representation methods, it is comparatively easier to build explanations facility in the Rule-based expert systems.
2) It is also simple to modify the knowledge base by adding, deleting, or changing the appropriate rules.
3) Knowledge in the form of production rules can be easily understood so that even someone who is unfamiliar with a program can understand it.
4) The stored knowledge is separated from the inference engine. Therefore, the inference engine and the knowledge base can be modified without affecting each other.

As there is no predefined procedure for solving problems in expert systems, reasoning strategy is used. There are two overall strategies of this type – forward chaining and backward chaining. A backward-moving chain then develops. The important expert system shells available are VP-EXPERT, Insight 2+, IITM Rule, CLIPS, and VIDWAN. In the present study, VIDWAN is used and explained in brief here.

VIDWAN is a backward chaining rule based expert system shell. It supports a built-in interactive rule base editor, which can also be used to create/edit the rule base. Rule in VIDWAN have antecedents and consequents, which deal with attribute-value tuples. This can be overridden during a consultation by any other attribute, if necessary. VIDWAN supports a backward chaining inference engine with uncertainty handling. It supports explanation facilities such as *why* (why do you want to know that?), *shrl* (Show me a particular rule), *how* (How did you get the value(s) for a particular attribute?) and *shvl* (Tell me what values you have got for a particular attribute). The rule base can be created using any conventional text editor.

The system includes an interactive syntax-directed rule base editor that can also be used to edit the rule base. Facilities are provided to record user interaction in a file to obtain a log of a session. VIDWAN provides a friendly user interface using windows, cursor-selection of commands and online help. The user can save the responses given during the session in a file and load them during another run. This enables using standard stored test responses while debugging a rule base

A built-in report generator facility is also provided to design application dependent layouts for display of conclusions as well as for generating detailed reports consultation sessions.

Uncertainty

Most geotechnical engineering decisions are made on the basis of uncertain and insufficient information. For example, in the case of **SCHAR,** the user may not know exactly whether the soil is normally consolidated or over consolidated. Modeling uncertainty adds a new dimension to Expert System, modifying the way inference takes place.

Two types of uncertainty have been used in **SCHAR:**

a. Uncertainty associated with factual knowledge
b. Uncertainty associated with rules

The uncertainty associated with factual knowledge is included by "CERTAINTY FACTORS" (CF) for the user's response. The user's response consist of either a choice among alternatives or numerical data followed by a numerical or linguistic measure of the certainty in the answer; for example

"Soil is clay with high certainty CF=0.9"

Or "Soil is clay with high certainty".

In VIDWAN for non-numeric attributes (except special attributes) a standard mapping description is used while eliciting the value of CF from the user.

The description may be used to choose the appropriate CF for the answer. A more flexible mode of entry is also provided, which allows the CF to be any number –1.0 to +1.0 in increments of 0.1. The mapping description is just to aid the user.

EXPERT SYSTEM *SCHAR*

SCHAR is a rule-based expert system. To begin with consultation with SCHAR, program is loaded through VIDWAN shell. The shell asks the file name. Once the program is loaded, knowledge base is loaded, rules forming the knowledge base are compiled and a list of queries is developed; each query represents a rule. With the help of displayed message, the users can select one of the appropriate tasks (shown as " Soil classification by"- 1.Laboratory Test 2.Field Test). After selection next query appears and lastly comes to the conclusion with the soil type, properties and behavior of the soil for better evaluation of the soil suitability for different purposes. Output of the program, examples of the SCHAR is presented in the Appendix.

Application of Expert System Schar

Schar is a PC-based expert system for soil classification, soil properties and soil behavior. The expert system acts as an intelligent consultant and suggests the correct geotechnical properties of the soil advantages.

1. The expert system interface allows a simple, natural usage of soil by the decision maker. It allows for the comprehensive consideration of more aspects of the problem and the effect of more types of factors.
2. In addition to the classification and geotechnical properties, it also suggests the behavior of the soil so that the suitability of the soil for different use can be known in better way.
3. The calibration interface allows for easy and quick adaptation of the system to any type of soil by local personnel.
4. Explanation facilities, which are included in the existing SCHAR, make the user more confident in implementing the generated plan.
5. The expert system can play an important role in the transfer of knowledge to the new person to take decision on logical basis.

Geotechnical engineering is a complex subject. The prediction of correct properties and behavior of soil is a complex task. There are many different methods to predict the behavior, each with its own advantages and disadvantages. The correct selection of the soil is governed by the geological conditions, project requirements, type of construction, and method of analysis intended for design. All these require expert advice and SCHAR can be more helpful.

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