Design Code for Concrete Structures as an Expert System

Règlements techniques pour les constructions en béton et systèmes experts

Technische Vorschriften für Betonkonstruktionen als Expertensystem

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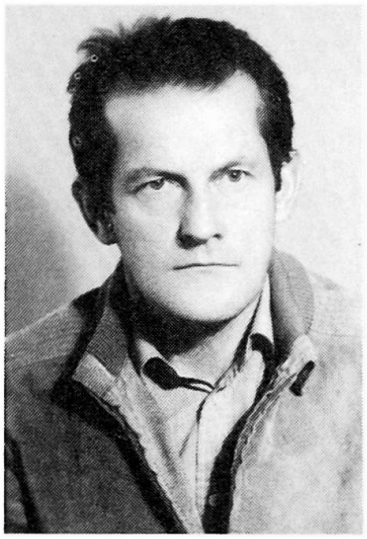

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SUMMARY
The reasons which stimulate the development of expert systems in the field of civil engineering and, particularly, in the field of technical provisions and design codes are discussed. The process of the creation of the knowledge base, using the Yugoslavian Code for Concrete Structures as a specific field of experience is described.

RÉSUMÉ
Les raisons expliquant le développement des systèmes experts dans le domaine de la construction, et particulièrement des règlements techniques, sont présentées. L'etablissement de la base des données, à l'aide des règlements techniques yugoslaves pour les constructions en béton, est mentionné à titre d'exemple.

ZUSAMMENFASSUNG
Es werden die Gründe, die die Entwicklung von Experten-Systeme in der Bautechnik und besonders im Bereich von technischen Vorschriften stimulieren, diskutiert. Der Prozess der Vorbereitung einer Datenbasis mit den jugoslawischen Vorschriften für Betonkonstruktionen als ein spezifischer Bereich von Erfahrungen ist beschrieben.

1. INTRODUCTION

As in other technical fields, expert systems are one of the possibilities for the more intensive use of the computers in the everyday work of civil engineers.

At present, the majority of the programs used in civil engineering practice are algorithmic programs, designed and applicable to "crunch" the numbers and to produce numerical and/or graphical results. The quality of the results is strongly dependent on the experience and knowledge of the user. He has to select different methods, prepare input data and last, but not least he has to review the results.

Many algorithmic programs comprise the knowledge about a defined problem. This knowledge is usually built into the particular statements of the program code and only rare people are able to change it. In contrast to these algorithmic programs, expert systems involve knowledge in a systematic and easily accessible form, called the knowledge base [1].

Regarding the fact that a greater part of the professional knowledge in civil engineering originates from experience and only a smaller part of the knowledge is of such a kind that it can be translated into different algorithms, it is possible to conclude that the use of the computers in civil engineering will be much more intensive and also more effective, if suitable expert systems are developed.

2. DESIGN CODES IN CIVIL ENGINEERING

Design codes are a very important resource and guidance in the work of civil engineers. The essential property of the design codes is that they involve a lot of knowledge, which is based on long term experiences. This knowledge is incorporated into many determinations and requirements in the codes. Rosenman and Gero [2] state that this knowledge is usually widespread and ill-structured. Consequently, finding and interpreting the necessary information is often difficult and time-consuming. This is not valid only for designers but also for other participants in the process from the idea to the construction of a building, its maintenance and demolition. It may be concluded that any systematic process should result in the reduction of errors or inconsistent decisions with resultant general benefits.

The number of codes which a civil engineer has to take into account in his work is very great. Therefore, a tool for the determination of all the relevant provisions to any given situation can solve one of the main problems facing the user. After the selection of the appropriate provisions, the civil engineer has to use them in different ways. Sometimes, he can use them directly but mostly he uses them as the data in his further work.

At present, this work is often carried out with different algorithmic programs and the problem of interfacing the codes and these programs is the second task which has to be resolved.

This article deals with the problem of the selection of those articles from the Yugoslavian Design Code for Concrete Structures, which are needed for a defined user in a given situation.

3. CHOICE OF TOOL FOR BUILDING EXPERT SYSTEM

There are two extreme possibilities for the development of an expert system. The first one is the application of an artificial intelligence language and the other is the use of an expert system shell. Although the expert systems which are developed using an artificial intelligence language are very effective, the development of such expert systems is time consumming.

This is the reason that many expert systems have been developed using the expert system shells available on the market. Particularly the expert system shells, which are installed on microcomputers, are very usable. The best property of these expert system shells is a low price, which make these shells accessible to everybody.

Because of the mentioned facts it was decided that the treated problem will be solved through the transformation of the contents of the code to the knowledge base of the expert system shell which must have the following properties:

- the knowledge is represented by the rules,
- the inference mechanism uses backward and forward chaining,
- the user interface, explanation facility, and knowledge acquisition facility are available,
- the possibility of calling other DOS programs is available,
- the use of DBASE files and worksheets is possible,
- "the chaining" of many knowledge bases is possible,
- the expert system shell runs on microcomputers (IBM PC or XT/AT compatible).

4. YUGOSLAVIAN DESIGN CODE FOR CONCRETE STRUCTURES AS THE KNOWLEDGE BASE

The Yugoslavian Design Code for Concrete Structures is based on the Model Code for Concrete Structures CEB-FIP [3]. The code comprises twelve sections. The first section involves general determinations and explanations of symbols. The second section involves the regulations on materials for concrete and the third section the regulations on steel for the reinforcement. The fourth section deals with the rudiments of the calculation of internal forces, stresses and displacements, using different methods. The fifth section involves the rules for the reinforcing. The sixth section deals with the design of the concrete elements and structures. The seventh section involves the process of constructing a concrete structure. The eight section involves the estimation of the quality of the concrete in a structure. The ninth section involves the test loading. The tenth section deals with the complementary proof of the quality of the built-in concrete. The eleventh section involves the maintenance of the buildings. The twelfth section involves final provisions.

The code is composed of 291 articles, 57 figures, and 29 tables. The code is written on 112 typed A4 pages. Up till now, the text and tables have been included in the knowledge base, however the figures are only mentioned.

The code is used by different users. The most important are: producers of concrete, producers of reinforcement, contractors, designers, and supervisors.

Some of them use only a part of the code, the others use many parts of the code. Some parts of the code are used by only one user, the others are used by many users (Fig. 1).

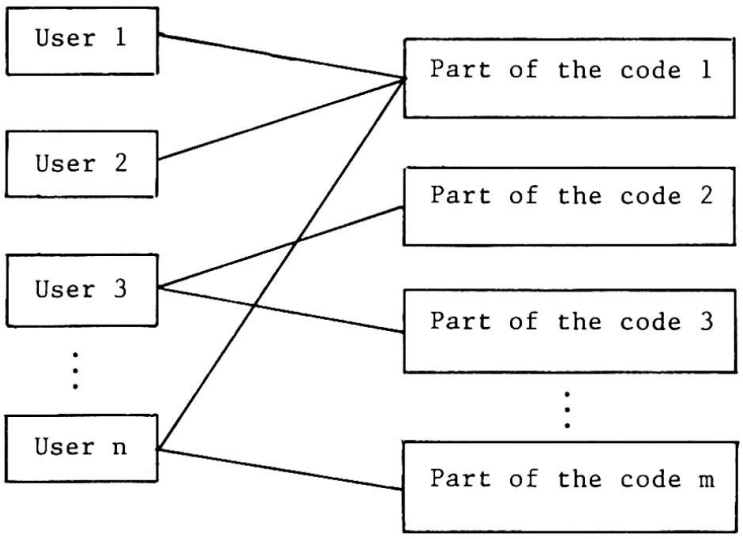

Figure 1. The interests of the users for the different parts of the code

Because of the extension of the code, many knowledge bases are used. These knowledge bases are formed accordingly to their users. As a consequence of the different interests shown in Figure 1, some parts of the code are included in many knowledge bases.

The first knowledge base (named CHAIN) involves the rules which define "the chaining" of the knowledge base used by a defined user. A part of the contents of this knowledge base, written for the expert system shell VP-Expert [4] is shown in Figure 2.

```
          .
          .
          .
          FIND way;

     RULE 1
          IF user = producer_of_concrete
          THEN CHAIN procon
               way = known;

     RULE 2
          IF user = producer_of_reinforcement
          THEN CHAIN proste
               way = known;
          .
          .
          .

     RULE 5
          IF user = designer
          THEN CHAIN design
               way = known;

ASK user; "Who is the user of this expert system?"
CHOICES user: producer_of_concrete, producer_of_reinforcement ...
              designer;
```

Figure 2. The contents of the knowledge base CHAIN

The statement FIND causes forward chaining in the inference mechanism of the expert system shell, the statement ASK puts the question to the user and the statement CHOICES generates the menus, where the user can select the answer.

The contents of the knowledge base CHAIN is metaknowledge: knowledge about where it is possible to find the knowledge which is of interest for a defined user.

As mentioned before, the code is composed of many articles. The articles have different contents:

- the complete contents can be transformed into the rules,
- only a part of the contents can be transformed into rules,
- no part of the contents can be transformed into rules.

The final result of the expert system is the printout of the articles, which are needed by a user in a given situation. In the first case, the article is not printed out. In the second case, only the parts of the article, which are not able to be transformed into rules, are printed out. In the third case, the article is completely printed out.

The complete contents of the code is separated in five main knowledge bases: PROCON for the producers of concrete, PROSTE for the producers of reinforcement, CONTRA for the contractors, SUPER for supervisors and DESIGN for the designer. Some of them are composed of many sub-knowledge bases.

Typical rules in these knowledge bases are shown in Figure 3.

```
RULE 7
     IF concrete = B_II
     THEN WHILEKNOWN have
               RECEIVE art_0\art 7,have
               DISPLAY "{have}"
          END
          WHILEKNOWN have
               RECEIVE art 0\art 8,have
               DISPLAY "{have}"
          END
          WHILEKNOWN have
               RECEIVE art 0\art 10,have
               DISPLAY "{have}"
          END
     end = here;

RULE 8
     IF sections = materials AND
          material = cement AND
          cmt = have
     THEN WHILEKNOWN have
               RECEIVE art 0\art 11,have
               DISPLAY "{have}"
          END
     printout = ok;
```

Figure 3. Typical rules in knowledge base PROCON

5. CONCLUSIONS

The expert system described in this article can be used in different ways. It is possible to use it in the education process, in the practical work of inexperienced civil engineers, and for the documentation of the work of experienced users. The preparation of the knowledge base for the other national codes can be carried out in a similar way, if the structure of the codes is alike. The possibility of the processing of the figures will influenced strongly the effectiveness of the system.

If the code changes, changing the knowledge base is easy.

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