

REPCON - AN EXPERT SYSTEM FOR DIAGNOSIS AND REPAIR OF DAMAGES AT CONCRETE STRUCTURES

REPCON - EIN EXPERTENSYSTEM ZUR DIAGNOSE UND REPARATUR VON BETONSCHÄDEN

REPCON - UN SYSTEME EXPERT POUR LE DIAGNOSTIC ET LA REPARATION DE DEGATS DE STRUCTURES EN BETON

Gabriele Funk

SUMMARY

Expert systems are computer programmes which work differently from for instance spreadsheets or word processing programmes. They communicate with the user during the consultation. The inference engine of the expert system processes knowledge of the knowledge base and the user's input data and then draws conclusions. Intelligent abilities are required for that kind of performance.

The user is supposed to be experienced in the field of the expert system's knowledge base. In so far, expert systems should be understood as computer programmes for experts rather than devices that make the expert redundant.

REPCON is a rule-based expert system for diagnosis and repair of damages at concrete structures. REPCON stands for REPair of CONcrete. A prototype was completed by Sohni (1991) at Darmstadt University. The knowledge base consisting of about 400 rules is implemented in an expert system shell which runs on personal computers. Its explanation system helps the user to follow the programme's reasoning during the consultation. REPCON is designed to support the engineer or graduate student as a consultant. At Stuttgart University it has become part of a programme for graduate students in that same field of damages at concrete structures.

The development of a new version of REPCON is in progress. The new version is based on a different expert system shell which is object-oriented and rule-based. Several further abilities will become part of the new version.

ZUSAMMENFASSUNG

Expertensysteme funktionieren anders als herkömmliche Computerprogramme wie z.B. Tabellenkalkulations- und Textverarbeitungsprogramme. Auch während des Programmablaufs stehen sie mit dem Nutzer in Kontakt. Die Inferenz-

maschine des Expertensystems verarbeitet Wissen der Wissensbasis sowie Informationen, die der Nutzer während des Programmlaufs eingibt, um dann daraus Schlüsse zu ziehen. Für eine derartige Vorgehensweise werden intelligente Fähigkeiten benötigt.

Es wird vorausgesetzt, daß die Anwender von Expertensystemen auf dem Fachgebiet der Wissensbasis des Expertensystems Erfahrung haben. Insofern sollten Expertensysteme eher als intelligente Unterstützung für Experten verstanden werden als Programme, die den Experten ersetzen.

REPCON ist ein regel-basiertes Expertensystem zur Diagnose und Reparatur von Schäden an Betonbauwerken. Der Name "REPCON" steht für "REPair of CONcrete". Ein Prototyp wurde von Sohni (1991) an der Technischen Hochschule Darmstadt im Februar 1991 fertiggestellt. Die Wissensbasis, die 400 Regeln umfaßt, ist in einer Expertensystem-Schale implementiert, die auf Personal Computers läuft. Die Erklärungshilfen des Programms zeigen dem Nutzer den Gang des Programmablaufs an. REPCON wurde entworfen als Berater für Ingenieure und Studierende. An der Universität Stuttgart wird REPCON in der Lehrveranstaltung "Bauschäden und Instandsetzung" für Vertiefung vorgestellt und von den Studierenden in Übungen angewendet.

Eine neue Version von REPCON wird derzeit entwickelt. Die neue Version wird mit einer neuen Expertensystem-Schale erstellt, die im Gegensatz zur Expertensystem-Schale der ersten Version objektorientiert aufgebaut ist. Jedoch werden weiterhin Regeln Bestandteil des neuen REPCON sein. Es ist geplant, weitere Einsatzmöglichkeiten für REPCON über die der ersten Version hinaus, zu entwickeln.

RESUMÉ

Systèmes experts différent des programmes traditionnels comme, par exemple, des tableurs ou des logiciels pour le traitement de texte. Ils sont en contacte avec l'utilisateur pendant le déroulement du programme. La machine d'inférence du système expert utilise le savoir de la base de savoir aussi que des informations introduites par l'utilisateur au cours du déroulement du programme pour en tirer des conclusions. Pour un tel processus, des facultés intelligentes sont indispensables.

Il est présupposé que les utilisateurs de systèmes experts sont expérimentés dans le domaine de la base de savoir. En ce sens, on ne devrait pas comprendre des systèmes experts comme des programmes qui replacent l'expert mais comme un support intelligent de l'expert.

REPCON est un système expert basé sur règles pour le diagnostic et la réparation de dégâts de bâtiments en béton. Le nom "REPCON" est

l'abréviation de "REPair of CONcrete". Un prototype, était achevé par Sohni (1991) à l'université technique de Darmstadt. La base de savoir, qui comprend 400 règles, est implementée dans une enveloppe de système expert qui marche sur des ordinateurs personnels. Les explications du programme indiquent à l'utilisateur la marche du programme. REPCON était projeté comme consultant d'ingénieurs et d'étudiants. A l'université de Stuttgart, REPCON était introduit dans la leçon "Degâts de construction et Reparation" et est utilisé par les étudiants au cours des pratiques.

Une nouvelle version de REPCON est en train d'être développée. La nouvelle version est construite à l'aide d'une nouvelle enveloppe de système expert, qui, à l'opposé de celle de la première version, est structurée par objets. Des règles, cependant, seront toujours éléments du système nouvel. Il est projeté de développer d'autres applications - au-dessus de ceux de REPCON - pour le nouvel REPCON.

Keywords: Concrete Damage and Repair, Expert System Shell, Rule-Based Expert System, Object-Oriented Expert System, Inheritance of Characteristics, Training Application, Explanation Facilities, Reasoning Process

1. REPCON - THE CONSULTATION

At the beginning of a consultation the user is asked for some basic data about the concrete structure in question and the appearance of the damage at the surface. Considering this basic data the programme asks for further information which could become relevant. At each step in the programme flow the acquired data is taken into account while asking questions about more details and consciously leaving out others. Those questions which are not asked wouldn't bring any progress as associated data which is already known wouldn't match.

Help properties specify text or graphics that explain or elaborate on the prompts that appear on the screen during a consultation. For example, there is a graphical aid available for answering the questions about the kind of crack the damage is. Pictures of specific appearances of several cracks are

shown on the screen.

The program is equipped with a special printing facility which produces printouts of the consultation in high quality. The client does not need to record the computer session himself.

2. REPCON - THE USER

The expert system REPCON with its explanation facilities helps structural engineers and graduate students as a consultant. Users on this educational level also know the required terminology which is necessary for the beneficial use of REPCON.

Engineers in consulting firms and bigger construction companies have some experience. They may use the programme to accelerate the process of diagnosis or get an idea more quickly of how to repair the defect structure or just being supported by the programme in their work. Remembering all relevant aspects may be more time consuming without using that aid. REPCON is also a training facility for civil engineers who deal with concrete repairs less frequently.

3. REPCON - ON THE BASIS OF AN EXPERT SYSTEM SHELL

As REPCON is designed by experts on the field of its knowledge base questions concerning information technology have to be subordinate. Therefore an expert system shell is the basis of REPCON. Expert system shells are expert systems with an empty knowledge base. There are expert system shells available for different aims like, for instance, planning or diagnosis.

3.1 The knowledge base

Like MYCIN (a medical expert system that helps to diagnose infectious diseases and gives advices in antibiotic therapy) REPCON too contains facts in form of parameter-value-pairs and rules which connect these facts in domain relations. These rules consist of a premise part which contains a set of preconditional facts and the conclusion in form of parameter-value-pairs. Most rules incorporate a "certainty factor" which links the rule's conclusion with a specific degree of certainty. Certainty factors also take into account a degree of the client's doubt in responding to a question by the programme. New certainty factors are calculated when previously existing certainty factors have to be combined with those currently occurring.

REPCON, in its new version just being developed, is based on an object-oriented and rule-based expert system shell which runs under Microsoft-Windows. Object-oriented development means that the components of the knowledge are represented as objects. The hierarchy of objects allows inheritance of characteristics between objects. This structure guarantees a high level of clearness and the possibility to expand the hierarchy at any point and at any time without troubling the existing structure.

3.2 The inference engine

For building the first version of REPCON an expert system shell was selected which works like MYCIN which is rule-based. In so far it deals with similar problems like diagnosing a defect and proposing treatment.

The programme flow of the first version of REPCON is backward chaining which means that in the reasoning process the program steps from higher-order goals to lower-order goals. Those "goals" are special parameters with unknown values. Goals start the process of reasoning and keep it running up

to the end of a consultation. During the consultation rules have to be found whose conclusions match the goal and set values to the goal parameters. - Backward chaining is the common procedure in diagnosis. First, the structure and the damaged outer appearance of a structure must be described before the program starts the diagnosis and finally finds an adequate measure of repair. During that process the user is asked when data is needed to apply a rule.

Like in the first version of REPCON also the new REPCON will contain rules and goals which represent the criteria used to make decisions and come out with a diagnosis respectively. While the first version of REPCON searches for rules that conclude a value for a frame's goal-parameter in the new version of REPCON goals are defined slightly different. Here goal-parameters with predefined values are tried to be verified during a consultation.

The expert system shell of the new version of REPCON can also do forward chaining. This reasoning process is event-driven (in contrary to backward chaining which is goal-driven). It is touched off by the entry of a new fact during the consultation and then flows through on the consequences of this change of the data base. This kind of reasoning process will be applied for making prognoses.

4. REPCON - THE PROCESS OF DEVELOPMENT

First the object hierarchy is developed which represents the basic knowledge about concrete structures and possible damages. Then rules and relationships are formulated after studying technical literature, technical descriptions of repair materials and regulations for instance. In interviews with experts further information has been collected. The first version of REPCON with its 400 rules is the basis.

So far the object hierarchy of the new version of REPCON has four main classes [fig. 1]. The class "Building Components" and its subclasses contain aspects of the building like its exposure, its dimensions and aspects of the production process. "Loads" and its subclasses describe different kinds of loads like physical and chemical ones. The class "damages" and its subclasses comprise characteristics of different appearances of damages. Repair measures for carbonated and chloride contaminated structures according to regulations by DAfStb (German association for reinforced concrete) are part of the class "repair". Also crack repair is described. This has already been part of the first version of REPCON.

5. REPCON - FOR EDUCATION AND TRAINING

Different levels can be distinguished of how sophisticated a computer programme for education and training tasks is designed. There are regular computer programmes like spreadsheets which only apply algorithms; the programme is a job aid which helps the user to solve a small problem.

More "intelligent" computer programmes can correspond with the user, the user can find out about relationships between parts of theoretical knowledge or can see how the programme proceeds in solving a more complex problem. This expert system is not an algorithm as it is applied when no algorithms are known. Its knowledge consists of rules and heuristics.

The programme's goals can be understood as reasoning steps. It is assumed that this sequence of steps, provided by a human expert, makes sense to the user during the consultation. An important facility that is used in training applications is the ability to explain its line of reasoning. There are two kinds of explanation facilities offered by the expert system shell of the first version of REPCON:

REPCON - first version

BUILDING COMPONENT	Parameters	Rules
	<ul style="list-style-type: none">* age* concrete grade* function...	<ul style="list-style-type: none">* calculation of nominal cover* exposure classes* calculation of minimum cover...

CAUSES OF DAMAGES	Parameters	Rules
	<ul style="list-style-type: none">* chloride content* damage appearance* carbonation depth...	<ul style="list-style-type: none">* attack of acid* alkali - aggregate reaction* concrete quality...

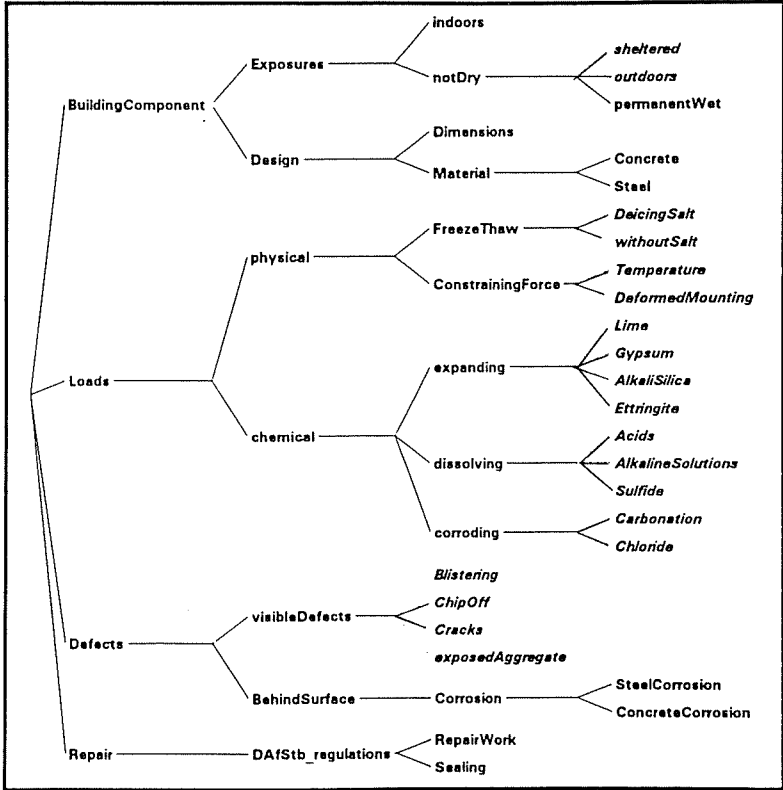
REPAIR	Parameters	Rules
	<ul style="list-style-type: none">* shotcrete* damage by fire* sealing...	<ul style="list-style-type: none">* repair according to DAfStb* crack repair* sealing...

PROGNOSIS	Parameters	Rules
	<ul style="list-style-type: none">* remaining service life* exposure conditions* corrosion rate...	<ul style="list-style-type: none">* calculation of remaining service life* reduced stability* calculation of corrosion rates

FRAME - STRUCTURE

Fig. 1 STRUCTURE

REPCON - new version



OBJECT - HIERARCHY

The "how" command tells the student how the program concluded about an information when it was assigned by a means other than explicitly asking.

The "why" command explains why an information is needed the program is asking for.

The programme cites the rule it is trying to use and tells the user what this rule is about. Moreover, the user can ask why the rule cited is needed and thus continue to follow the trail of logic to its beginning.

These explanation facilities make it easier to get to know the reasoning process step by step. The student can vary his answers to the programme's questions in each consultation to find out about the changes in the further way of searching for the conclusion depending on that varying data. In that respect, the student is "learning by doing".

Tutorial programmes are on the highest level of performance in education. These programmes have teaching expertise, such as the ability to adapt the presentation to the students competence. The student himself has to find a way of reasoning. The tutorial program comments on this by praising or correcting the student's attempts. GUIDON which is designed on the basis of MYCIN is an example for tutoring systems.

6. CONCLUSIONS AND FURTHER STEPS

REPCON has been designed as a consultant for engineers. It is a rule-based expert system which diagnoses damages at concrete structures and indicates repair instructions. The extensive knowledge base of REPCON includes a lot of facts and relations. The user does not only have access to this knowledge base to just ask for a diagnosis and a way of repair but also learns about

REPCON 's process of reasoning.

REPCON in its first version proved that an expert system can be a professional aid dealing with damages at concrete structures. The following characteristics of REPCON stand for its special quality:

- Because of its ability to communicate with the user during the consultation the programme only asks relevant questions. Therefore, it comes out with a conclusion more quickly than a regular type of programme which processes the same amount of information.
- Comparing the amount of the user 's input data available with the amount of information necessary to conclude the goal REPCON comes out with a conclusion with a certainty according to the degree of completeness of the input data base. If only little information is available the conclusion is of a smaller degree of certainty. The user has the possibility to add a degree of certainty to his answer. Both kinds of certainty are taken into account in REPCON 's conclusions.
- Printouts give the user a report of the entire consultation containing all the user 's input data. Also, overall information is documented in those reports about the nature of causes for concrete damages and descriptions of repair measurements.

REPCON in its new version will cover the whole knowledge base of the first version and new parts will be added. The new version of REPCON is more clearly arranged because of the object hierarchy. Therefore it will be more suitable for the greater number of tasks and the greater knowledge base.

The first version of REPCON does not contain all relevant causes of concrete damages. The part of proposing repair measurements is not complete either. Completion of the knowledge base has to be reached.

There are plans to link REPCON to a computer programme that designs calls for bids and has spreadsheet abilities to also take into account the cost aspect of repair measures. A more elaborate programme component about prognosis of damages will give the basis for considerations about the most appropriate repair measurement. REPCON will also question on economic and esthetic aspects concerning overall real estate considerations which also influence repair recommendations.

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