USING EXPERT SYSTEMS IN THE MANAGEMENT OF INDUSTRIAL EQUIPMENT MAINTENANCE

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ABSTRACT: *The term "expert system" generally evokes new management techniques in various fields of activity. The definition of the expert systems in terms of their architecture reveals three basic elements: the knowledgebase containing specialized knowledge in a certain area, taken from the human expert in that field; the facts which include information related to the situation of management and data concerning a certain problem to be solved and the inference engine which is intended to exploit the set of knowledge in order to solve the problem. Examining the causes of equipment failure and malfunction is a central application field of expert systems.*

KEY WORDS: *expert system, data base, the knowledgebase, the facts, the rules, the inference engine*

1. GENERAL PRINCIPLES IN CREATING EXPERT SYSTEMS

Examining the causes of equipment failure and malfunction is a central application field of expert systems or of data bases, in general. The term "expert system" generally evokes new management techniques in various fields of activity and they are now referred to as "the content of a data base management".

The appearance of these systems was possible due to the development of the artificial intelligence in a computer field. The theoretical analysis of expert systems both in the field of informatics and in mathematical logic has been the subject of several studies prepared by well-known analysts of the two areas.

As far as the content of expert systems is concerned, this analysis must begin by explaining the basic terms:

- The concept of "expert" has the general meaning of a certification of a person or of a system to have extensive knowledge in a field. Thus,

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according to Romanian Dictionary, this term is given the following definition: "A person competent in a particular area or a person required to make a survey in a given field."

- The concept of "expert system" refers to a program that uses specific knowledge from various fields of activity in developing a resolution for each problem that may occur in a well-defined area. Therefore, the expert system "aims at making use of a person's experience and knowledge in order to replace him." This lays the foundation of a "knowledge base" which is one of the main components of these systems in relation to information systems. Expert systems also involve the development of a "database", a flexible database not a rigid one like in the case of information systems; in expert systems it is known as the "basic facts".

In defining expert systems in terms of their architecture, as mentioned in the composition of these systems and in the applications of these systems, we can identify three key elements. The basic representation of an expert system through its basic components in the context of its use in industrial maintenance can be seen in Figure 1, where we can identify:

- *The knowledgebase* - containing specialized knowledge in a certain area, taken from the human expert in that field. Regarded as general, knowledge reflects the "objects" of the real world and the relations between them. There are several methods of representing knowledge, among which the most important are: semantic networks, production rules and frames.
- *The facts* contain information regarding the situation of management, and data concerning a certain problem to be solved, the enunciation of the problem and the facts resulting from the arguments given by the inference engine regarding the knowledge base.

  However it is necessary to distinguish between the knowledge describing the ways of solving certain problems and the facts presenting initiation statements of that certain type of problem.
- *The inference engine* is intended to exploit the set of knowledge in order to solve the problems and it represents the actual element of processing expert systems, which starting from the facts (input data of the problem), activate specific knowledge from the knowledge base, thus revealing judgments that lead to new facts called new facts.

  Thus, this method builds a solving plan depending on the specific problem, using knowledge from that field, as a result of rendering the inference engine into function. In a certain context, taking into account the nature and the characteristics of the solved problems, the knowledge base is enriched by adding new elements or by modifying existing ones.

  In conclusion, the inference engine is a program that implements judgment algorithms such as: deductive, inductive, and mixed, but which is independent of the knowledge base.

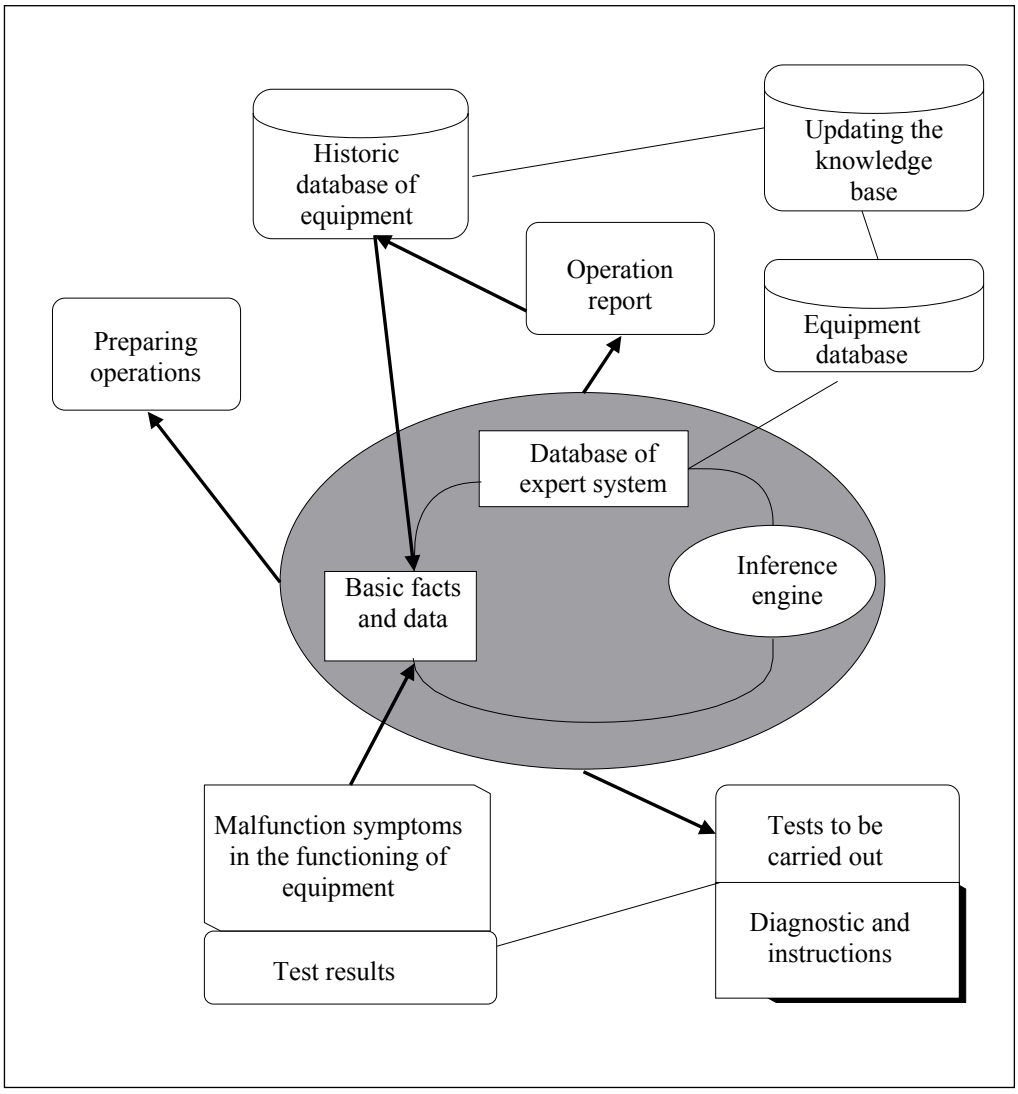

Figure 1. Basic representation of an expert system in industrial maintenance activity

2. TECHNICAL ASSISTANCE OF EXPERT SYSTEMS IN INDUSTRIAL MAINTENANCE

Modern techniques used in computer-aided industrial maintenance can be grouped into three types of characteristic systems, each of them being associated with different ways of solving the maintenance problems of technological equipment:

1. *Support system to increase operational availability of technological equipment*. This type of system uses computers to ensure the optimal availability, which means solving two main functions:

- a function to acquire data on the operation of technological equipment which can be achieved by implementing a system connected to automated processes;
- the processing of information;
- the results of these processes will be presented either in accordance with the operation regulations of works established within the industrial unit or based on some general rules accepted by it.

2. *Support systems for the diagnosis of malfunctions*. Support programs regarding the examination of the initial causes of equipment malfunctions can be various and they can have different configurations; among these it is worth mentioning the following:

- Integrated Systems such as piloting programmable automatons; this type of system is designed for equipments with digital controls. These systems operate based on special programming completed with programs tailored for calculating the parameters of tracking equipment, programs that can exceed the basic volume;
- Diagnosis systems or data acquisition systems, which provide real-time comparison of the cycles or of the states of a piece of equipment subject to monitoring in relation to the good working state from the beginning or as it was theoretically established. These systems are programmed so that they can be provide with a continuous training in relation to events occurring in the functioning of the equipment in question;
- Programmable diagnostic systems encourage the setting of a pre-diagnostic and they control simultaneously the operation of technological equipment in terms of production achieved;
- Expert system generators allow the examination of the initial causes of equipment malfunctions and must be connected to the database of the main system.

3. *Expert systems*. Expert systems used in the process of diagnosing the operation of equipment are characterized by the existence of limitations due mainly to the skills of human experts in the research conducted at the beginning of the expert program as well as to the possibility that the expert program can permanently train itself, just like a human expert can train himself in his daily activity.

Regarding the ability to train expert systems, it is worth mentioning the fact that they use formal rules in the training processes, which makes these systems similar to an apprentice in equipment troubleshooting and diagnostic techniques.

Moreover, we can take into account the hypothesis that human intelligence may be the object of a transfer towards the knowledge base of the system, since the limits of the self-training ability are acknowledged for this type of systems as well. Verifying the equipment used in creating an expert system; the validation of resolutions; the analysis of the system's efficiency; calculations of profitability; opportunities for improving (after the implementation of the system) the characteristics of accuracy and speed of the system; all these represent elements which contribute to the success of using expert systems in industrial maintenance.

Regarding the use of these systems in industrial equipment maintenance, we forward a list of questions which should include:

- if an investment in this area is achieved, is there a possibility for another facility to take advantage of the implemented system or is it necessary to establish a new application?;
- who of the specialists should be called upon to explain some specific aspects of using the system?;
- is the conceptual characteristic of the system going to bring about the risk of having, after implementation, a program incompatible with the company's computer system?;
- can the recommended system be put into operation in time to eliminate probation costs and the temporary malfunction costs that may occur at the beginning?

3. KEY ASPECTS OF THE ACTIVITY OF EXPERT SYSTEMS

3.1. The stages of the basic cycle of an inference engine

The inference engine represents the heart of an expert system, due to the fact that using the knowledge base; it can build dynamic judgments by running the rules which are to be implemented and establishing their order. Regardless of the method of reasoning, the basic cycle of an inference engine undergoes four stages: selection, filtering, conflict solving and the implementation itself (activating conflicts and implementation).

The selection stage extracts among the rules and the facts the elements which characterize the sub-field of solving the problem; that is to say, we can create a partition of the knowledge base that will shorten the period of time needed to search for the next stages. This phase is necessary when the knowledge base is big enough, trying to cover more fields of knowledge. Filtering means to compare assumptions, the rules previously selected with the facts that characterize the problem to be solved, in order to determine the subset of active rules. If we do not get any active rule, that means that we experience failure, a situation which the expert system must explain or in which the user must answer a series of questions asked by the expert with a view to complete definition of the problem.

Solving conflicts is necessary when the filtering stage resulted in more rules that can be used and only one should be chosen for implementation. Among the main choosing criteria that can be used during this stage, it is worth mentioning the first rule in the list, the most complex one (the one with the greatest number of facts in the premise) or the one which is used more often.

The performances of the inference engine depend on the quality of this choice; thus a solution to the problem can be found easier or harder. It is difficult to indicate one or the other among the criteria, because this choice depends on the context in which the knowledge base can be found at that certain time. The implementation of the rule chosen consists in adding one or more facts to the facts system; during this stage it is also possible to resort to external procedures, to having access to the database and to table processors, or to ask the user several questions. In order to solve a problem, the

inference engine must run several basic cycles and it should stop according to the type of reasoning used.

3.2. Types of reasoning

The inference engine can use three types of reasoning: deductive reasoning (going forward), driven by facts; inductive reasoning (going backwards), driven by purpose and mixed reasoning.

3.3. Deductive reasoning

In this type of reasoning, the inference engine, starts from the facts and looks for a specific purpose or objective. The filtering phase consists in extracting from the knowledge base only the rules that have as premises facts which define the problem, that is to say input data. After the phase of solving conflicts, we can choose a single rule to be enforced. The process repeats itself until the intended purpose is achieved, or until there are no more rules to be implemented, in which case we experience failure.

The stages of this type of reasoning are the following:

- initial input of facts and purposes;
- the beginning of reasoning - the filtering stage, determining active rules, checking the set of active rules (if empty or not);
- implementation: the stage of conflict solving, implementing chosen rules, changing active rules.

Deductive reasoning brings two major advantages, namely: encourages the generation of all possible solutions; provides an enrichment of the facts in each cycle of the inference engine, which further simplifies deductions.

However, this way of reasoning has some disadvantages, such as:

- the facts must contain sufficient data so that the system reaches its target, that is to say the problem can be is defined in detail;
- all applicable rules are implemented, even if some of them are not interesting;
- in certain situations, when number of rules and facts is very high and the target cannot be achieved, there is a risk of reaching a combinative explosion regarding the number of basic cycles of the inference engine;
- is not interactive during inferences, which makes it possible for the user not to be questioned or admonished for the situation in case of a wrong solution / decision that comprises a small number of unknown facts during the process of system analysis.

3.4. Inductive reasoning

This reasoning begins with the purpose, with the problem to be solved, and divides it into sub-problems until we get primitive problems or proven or questionable facts. Therefore it is said that this way of reasoning is driven by the purpose to find the

facts which help achieving targets, unlike deductive reasoning. Selected rules are those which have the initial purpose specified in conclusions and the premises will become sub-purposes that need to be determined. This process is repeated until all sub-purposes are demonstrated or until the set of rules from the filtering stage is null, which reflects failure.

By summarizing these steps we obtain the following algorithm:

- introduction of the problem;
- start processing - filtering stage;
- determining the rules or applicable rules;
- checking the rules (if it is empty or not);
- implementing the program - the stage of solving conflicts;
- the stage of implementing additional rules;
- keeping the premises from the chosen rules;
- creating sub-purposes;
- if the problem is not solved, the cycle resumes.

The main advantage of this method of reasoning lies in the need of a small internal memory, because the search engine is very small. Another advantage lies in small period of time needed to find solutions because the search is made only for the sub-purposes which have a chance of validation.

4. CONCLUSIONS

The implementation of an expert system in the industrial maintenance activity may bring benefits to the company, among which we mention:

- reducing the time to diagnose the causes which led to malfunctions; permanent availability of a tool for diagnosing malfunctions;
- creating a database regarding the operation of technological equipment;
- creating a knowledge base regarding the flaws of technological equipment and how they were resolved in the past;
- the ability to simultaneously benefit from the knowledge and the experience of experts in solving a malfunction of a piece of complex equipment.

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