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IMPLEMENTING EXPERT SYSTEMS IN ENGINEERING

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Abstract: Expert Systems are based on capturing the corresponding expertise from the human experts and conveying it into a computer through a knowledge base. A knowledge base is a collection of logical propositions whose relationships model the knowledge about a certain topic.

In this paper the principal issues to be taken into account to apply successfully the Expert Systems technology to decision making in engineering are discussed.

Keywords: Expert Systems, Decision making, Engineering

1 INTRODUCTION

During the last decade the development of production systems oriented to greater quality, productivity and flexibility has been a top issue in the production planning all over the world. These systems are based on a better understanding of the production process and the characteristics and properties of materials as well as on the availability of better equipment and instrumentation, that is, a high level of engineering and technology.

Not withstanding these scientific advances, engineering decisions are made however taking into account a combination of: [1]

A) Scientific theories and analytic techniques
B) Experimental methods
C) Last but not least, individual experience and expert judgment as well as common sense.

This last fact means that the human expertise is actually a very important component in the decision making process in Engineering.

The fundamental role of individual expertise in engineering is due to several factors including: [1]

a) Lack of specific information about the problematic systems tackled by Engineering;
b) Uncertainty in the information available about those systems;
c) The great diversity of phenomena and variables that affect the behavior of those systems;
d) The occurrence of unexpected situations and environmental conditions;
e) The complexity of the problems to solve;
f) Existing theories that are however only applicable to very specific cases and limited conditions.

Problems whose solution depends on empirical rules defined by an expert along his/her life experience are very common in engineering. In this sense, we find these empirical rules in the analysis, design and production phases of most technological products, as well as in the planning and management of the whole engineering process. As a consequence, there is a need to ask for the assistance of experts in the engineering and technology domains in order to have the proper solution, when a difficult problem is encountered.

In many situations there is however a lack of availability of highly qualified experts in engineering and consulting the existing ones can be very expensive. Moreover, experts are most concentrated in the largest cities. This means that decision problems in Engineering are not going to be effectively solved unless the reservoir of technical knowledge and the expertise of the existent experts are made available in the sites where problems originate. Besides, the process of knowledge transfer from an expert engineer to train a new expert engineer takes a long time.

The computer is a major breakthrough in engineering. It has changed the ways of making technical analysis and designs. Artificial Intelligence is the most dynamic field in computer science and technology and Expert Systems, also called Knowledge-based Systems, are one of the most fruitful areas of Artificial Intelligence. In fact, Expert Systems technology and Knowledge Engineering have proven to have a high potential to solve real problems where human experience has an important role because algorithmic solutions do not exist or are not adequate.

Knowledge Engineering captures the expertise from the engineers into a computerized knowledge base. . A knowledge base is a collection of logical propositions and conceptual definitions whose relationships model the knowledge about a certain topic. This knowledge base would then be the nucleus of a microcomputer inferencing and consulting program, a so called Expert System, that would be widely distributed among the users to help them to solve their technical decision problems.

2 ADVANTAGES OF EXPERT SYSTEMS

The advantages of an Expert System are:

Autonomy: After a knowledge-based system has been designed and implemented it becomes autonomous. This means that the system is physically independent from the system's developer and the domain expert. These people may go away but their knowledge remains captured in the system.

Reproducibility: A knowledge-based system and the knowledge it contains can be easily reproduced, if necessary, to thousands of copies in a few minutes, to broaden the user universe. On the other hand, a human takes years to become a fully skilled expert.

Low Purchase and Operation Cost: Having experts available at all times is very expensive. On the contrary, the cost of a knowledge-based system lies only on its design and development. These costs can be later distributed among all users of the system, making each single copy very cheap.

Disposability: The knowledge-based system can be easily distributed to different locations and it can also be used in difficult working conditions.

Flexibility to expansion and modifications: The information contained in the knowledge base can be easily updated to incorporate new technological advances, merely by accessing text files when these files are not part of the knowledge bases.

ARCHITECTURE OF AN EXPERT SYSTEM

The architecture of an expert system has five functional components:

1. The **Knowledge Base**, where the experts knowledge is stored. This knowledge is expressed as a series of known facts, captured in a *Fact Base* and a set of cognitive relationships that constitute a *Relatioships Base*.
2. The **Inference Engine** draws from the knowledge stored in the Knowledge Base new relationships and facts that complete the available knowledge and solve the problem if this problem is in fact solvable in the given environment.
3. The **Knowledge Acquisition System**, that permits to transfer knowledge from the experts to the Knowledge Base.
4. The **User Interface** that makes possible the communication between user and expert system.
5. The **Explaining Interface**, to have explanations from the Expert System about the procedure followed to get a certain conclusion or to explain the reason why some questions were asked to the user.

3 A SAMPLE OF EXPERT SYSTEMS APPLICATIONS IN ENGINEERING

Given the big number of small and medium sized enterprises and the increasing costs of energy, the National Commission for Energy Conservation in Mexico found that it would be of a great benefit to implement an energy conservation advisor system in this kind of industries. This system should focus on design as well as on simple maintenance and servicing measures, and should be based on the practical knowledge of energy experts, who would diagnose every case and prescribe the pertinent recommendations.

The Intelligent Systems Laboratory of the National Autonomous University of Mexico developed then a series of knowledge-based systems for energy conservation programs in small industrial and services enterprises.

The first Expert System to be developed was called SEILUM and was built for lighting systems analysis and design in small and medium sized industrial buildings, on the basis of energy savings criteria. [2]

The second Expert System in this area was called EXILCO; its purpose was to optimize energy consumption in lighting in commercial buildings and hotels.

Both systems calculate the energy used by a given lighting system according to illumination levels in the different areas of the building and recommend energy saving policies and measures to improve the efficiency of the lighting system. These Expert Systems were developed for the unskilled final user who wants to analyze a particular building illumination system to reduce costs.

Different lighting specialists validated both of the Expert Systems. They compared the results obtained by the systems against the reports of several studies performed by the government energy

agency FIDE in Mexico City along 1993 and 1994. The effectiveness shown by the Expert System was of 85% in average, with a cost reduction up to 60% compared to the cost of traditional studies. [1]

A third Expert System called ESCAF was built to design compressed air facilities for small and medium size plants in the cement, chemical, pharmaceutical, painting, glass, mining and textile industries and to review existing ones in order to optimize the energy used in such facilities. In this sense, for a new compressed air facility ESCAF provides adequately the type and capacity of the compressors and drying system if necessary, as well as the dimensions of pipelines and recommended accessories including cooling systems. All this information is given considering criteria of efficient usage of energy. For an existing installation, ESCAF provides an analysis of actual equipment and the necessary recommendations for an adequate supply of compressed air, according to energy efficiency. Moreover, for both cases ESCAF recommends appropriate preventive maintenance programs and allows the detection and correction of operative failures.

ESCAF was validated by expert engineers from a very prestigious international corporation dedicated to the design and manufacture of compressed air equipment. The experts made very positive evaluations of the performance of ESCAF and recommended it for internal use at their corporation. A license for unlimited use of ESCAF was given to that company. [3]

A fourth developed Expert System, TUTORES, is a tutorial Expert System, built for the training of technicians and engineers in the field of design and evaluation of cogeneration plants.

Within the field of efficient use of energy, industrial cogeneration of energy is a very efficient way to reduce the waste and to increase the supply of this important resource. However the bottleneck for the full implementation of this solution at the industrial sector level in Mexico lies on the lack of trained human resources for the design and operation of cogeneration plants. In fact, there are very few human experts in such field compared with the number required by industry.

In this sense, it was decided to develop a tutorial Expert System to provide technical training in the design, selection and evaluation of cogeneration plants, considering the new technologies available in the market. The users of this system would be engineering students, technicians and professionals interested in this theme as well as training departments of industrial corporations interested on this kind of energy saving measures.

Cogeneration specialists and instructors carefully validated TUTORES. Its evaluation took place at the National Commission for Energy Conservation in Mexico, in special courses designed to train people from the industrial and the public sectors. The results were excellent. [4]

4 ISSUES IN THE DEVELOPMENT OF EXPERT SYSTEMS APPLICATIONS.

Expert Systems constitute a new concept for most small and medium size corporations and local governmental agencies. This means that in most cases when the development of an Expert System was advised as the proper solution to a certain problem, we faced the conflicts derived from the introduction of technological innovations in organizations. In other words, the application of Expert Systems to industrial problems cannot be reduced to a mere technical implementation. In fact, it is a cultural assimilation process, resulting from the interaction between the development of the Expert System and the cultural and technological environment of the organization. Taking into account this environment and the people that could be affected by the system reduces the possibilities of a failure.

Some factors considered to promote the success of the Expert System assimilation are the following:

a) The client organization already has a core technology similar to this new one. For instance, a computerized data base system, a computer network and/or a management information system. This computer technology is already an integral component of the technological culture of the organization.

b) The organization has at least a middle or top executive, convinced of the new technology, and willing to play the role of "Technology's Champion". He pushes the project, defends it within the organization and convinces people to accept it.

c) To get real support from the final users, the development team involves them actively in the project from the very beginning, thus becoming helpers instead of obstacles of its implementation. This involvement assures that the user requirements are taken into account in the design. And at the same time, it results in the best way to train the users to operate the system and to gain their support for its implementation. This is also the ideal measure to avoid the "Not-Invented-Here" syndrome, consisting in the blocking out of every innovation coming from outside the organization, with a hard opposition.

d) The development team makes itself familiar with the problems of the organization, the problems of the final users within the organization and the characteristics of the environment before arriving to a proposal on how the Expert Systems technology could help to solve the problems. We consider the

requirements of the organization in order to explain the benefits of Expert Systems. Furthermore, it is taken care, not to oversell the technology, promising outstanding results beyond reality.

e) The development team tries to relate the Expert System to the available systems at the organization, as a useful "add-on" to the existing systems. This permitts to get the support from the management and the users, because they get new and useful capabilities out of their systems, which are difficult to obtain by another technology.

f) The Expert Systems team looks for solving real problems not invented ones. The aim is not to develop a system that never would be used.

g) The Expert Systems team tries to build and consolidate a trustworthiness environment in users and in the executives of the client organization about the real possibilities of Expert Systems in general and the proposed project in particular. To that purpose, the Expert System should be gradually implemented in order to validate it with the user since the very beginning. The best way to do that is to build a "rapid prototype" that contains only a few rules and very basic knowledge, but that could deliver "correct" results in a particular domain of the problem. We should install this first prototype in the user machines and encourage all kind of tests and feedback. Then we should abandone it and build successively larger versions, getting user feedback every time to improve the design. Finally we should end with a viable and operational final version. The development of the successive prototypes helps to train the own development team in the characteristics of the problem and at the same time to involve final users in the project, building a common language with them.

5 CONCLUSIONS

In this paper, some of the principal issues that were considered to apply successfully the Knowledge-based Systems technology in small and medium size enterprises were discussed, according to the experience at the Intelligent Systems Laboratory of the National Autonomous University of Mexico.

An important conclusion is that Expert Systems constitute a new concept for most small corporations and local governmental agencies. This means that in most cases the Expert Systems developer faces problems related to the introduction of technological innovations in organizations. In other words, the application of Expert Systems cannot be reduced to a mere technical implementation. In fact, it is a cultural assimilation process, resulting from the interaction between the new Expert System technology and the cultural and technological environment of the organization. Therefore, the development team should take into account this environment and the people that could be affected by the system, thus reducing the possibilities of a failure and paving the way to the technological innovation.

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