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THE APPLICATION OF EXPERT SYSTEMS IN MANAGEMENT DECISION MAKING

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Abstract: The aim of this paper is to present the principal characteristics, advantages and limitations of the new development approach of business decision making aid tools, based on Artificial Intelligence technology, and its main development tools: Expert Systems.

For this purpose, in the first section a conceptual introduction is done of the nature and fundamental characteristics of the kind of decision activity involved in the management process at business organizations. In the following one, some of the basic ideas developed in the Artificial Intelligence and Problem Solving's disciplines, suitable to the understanding of this work are presented. Finally, in the third section, we will try to do a short analysis of the implications and implementing posibilities of these new ideas in the field of management decision processes.

keywords: management, artificial intelligence, expert systems, decision support systems.

INTRODUCTION

The management of an enterprise - or any other type of organization - consists in a set of activities by means of a continous process of determining and obtaining objectives takes place. Tradicionaly, it is accepted that such a process involves a sequence of steps or functions, as planning, organization and control.

Now, as some authors, like Simon (1977), have pointed out, any manage-ment process involves necessarily a decision making process, because it consists in essence in segregating certain elements or parts in the decisions from the organizational members, to set up normal procedures to select and define such elements and communicating these procedures to the members affected. Business management, in a wide sense (strategic and tactical management) is closely linked to decision making. Inside the business organizations, a large number of decision processes take place at the same time, most of which are related to each other in a kind of collaborative interaction -by means of these management processes- to get the organizational goals.

1. Management Decision Making in Bussines Environments

As Riggs(1973) has noticed, a decision is merely a selection between two or more different alternative actions. The decision maker is faced up with several alternatives or different actions to do, and he chooses only one, usually based on his own resources, expectatives and preferences. Nevertheless, the action course's selection is nothing but the end of a long process, and the begining of another one, which will lead to the adoption of new decisions or the revision of those ones already adopted (Simon, 1977).

Maybe Simon has been the most relevant author who has grouped the larger number of disciples within the field of the theory and design of decision-systems. As he express, there are four different but closely related steps wihthin the decision making process: intelligence, design, selection and revision. The first one involves seeking into the environment or into the organization to found conditions that demand a decision. The second one has the purpose of the invention, development and analysis of the different options or alternative actions to choice, the study of their implementation's possibilities and the evaluation of their consecuences. In the third step, a specific alternative is selected among those designed at the step before, and in the last one, it is made an analysis of the outcomes from the adopted decision, which represents itself the beginning of a new cycle.

But finally, all decisions are carryed out to solve problems. Problems are obstacles interposed in the way to our objectives. If a situation does not need any decision, then there isn't any problem. Therefore, the selection of the organizational objectives will decide the types of problems that will arise and that will have to be solved. This idea drive us directly to a very important issue: the problem of the rationality in business decision making.

Bounded rationality and incomplete information

A brief introduction to the concept of rationality can be found in the Simon's work (1972), to whom the rationality reveals "a suitable kind of behavior for the consecution of a certain goals, whithin the imposed bounds of a set of conditions and some constraints given". The underlying idea in this assumption, is the fact of a goal-achievement oriented behavior, no matter who accomplishes such behavior or the nature of the goals to achieve.

For the so called "rational decision making view" (Keen and Scott Morton, 1978), a decision will be rational if it really selects the alternative followed by the preferred sequence of outcomes. The task of decision making for the rational decision maker implies tree intervenient events: 1) the identification of all the alternative actions, 2) the identification of all the consequences followed by each one of these actions and 3) the comparative evaluation of such a consequence series.

Obviously, it is very difficult given a certain complex situation, that the decision maker knows exactly the whole alternatives and all their consecuences, but this has been the paradigm adopted by the "economic man" from the classical Theory of the Firm, and the "probabilistic man" from the decision theory and games theory. If we assume the hipothesis of this rational decision making process, we have to accept that the decision maker's behavior won't be other but an optimizing one, in other words: nobody would accept the selection of any alternative if the best one is available.

However, the individual's real behavior within the organization does not reach the whole objetive rationality such as it has been proposed by the classical microeconomic theory, even not in approximate way. Bounded rationality comes from the incomplete information phenomenon and the human brain inability to apply on a single alternative all the relevant aspects of value and knowledge.

In his early work "Administrative Behavior", Simon characterizes the bounded rationality as a "residual" class; rationality is bounded when it doesn't exist a total knowledge. In a general sense, the task consists on replacing the objetive rationality of the economic man, by some kind of rational behavior which would be compatible with the availability of data and the individual's capability on information processing, in the sort of environment where he or she has to perform. From this point of view, two are the key concepts involved in any decision process: search and satisfaction.

First of all, unless the decision maker is provided which all the available alternative choices, usually he or she normaly will starts a process of searching them. In complex situations, with constraints of time and information, this searching cannot be exahustive.

Another concept involved in searching within the bounded rationality, is satisfaction. The impossibility to work with all the alternatives, and the difficulties in the evaluation of their consequences, reduce the possibilities on finding an optimal one. In that case, some kind of desire or aspiration level about the goodness of an alternative is setted up so, as soon as an alternative which fulfils the aspiration levels is founded, the searching process stops and this alternative is chosen.

In this context, the decision maker will not try to achieve the best possible solution available, but one which satisfyes the aspiration levels from the set of objectives, he or she is trying to achieve in some way. Then, the alternative chosen is called "satisfactory".

2. Artificial Intelligence and Problem Solving

An important amount of developments in decision making techniques during the last decades have emerged as a consequence of the relevant insigths that have taken place on the field of Operations Research, specially through the use of mathematical models (such as linear programming, multicriteria programming, bayesian analysis, and so). But these developments have been almost exclusively intended to aid in the well-structured decision making process, overcoming therefore a substancial part of all management decision making: the analysis of those decisions which due to their nature are ill-structured, requires judgement from the decision maker and takes place in a novedose way, are characterized by it's uncertainity or it's almost complete absence of information.

At the same time, during these years, some significant insights have taken place about the real nature of the human problem solving processes. The body of theoretical knowledge that has been built arround those findings may be encoded, at the moment, under the name of Artificial Intelligence (AI).

The researchs on the AI field have demonstrated (Newell and Simon, 1972), that the individual's decision making implies a very selective inquiry within feasible spaces of alternatives, usually huges. The selection is based in <u>heuristic rules</u>, and tends to direct and center the research in those parts of the total space "more ,promising", so that solutions or valid alternatives could be identified after the study of an only small parts of these spaces.

Together with the <u>heuristic search</u> paradigm, the sufficiency approach determines when the founded solutions are satisfactory. So that, these new experiences practically comes to confirm and are completely integrated within the bounded rationality paradigm.

The Artificial Intelligence concept

In a generally accepted definition, AI can be considered as a science and as a technology which deals with the understanding of intelligence and the design of intelligent machines, that is, machines presenting features related whit human mind, such as reasoning, natural language understanding (spoken or written), learning, decision making and some similars.

The AI research attempts to develop computer systems capable to carry out tasks normally associated with intelligent human behavior. Those tasks are referred to the fundamental cognitive processes:

- memorizing (data storing and retrieving)
- learning
- problem solving
- inference and logic deduction
- pattern recognition and perception
- decision making
- natural language understanding

Each one of these aspects, which represents a part of the overall human behavior, are complex enought to promote by themselves a differenciated domain of research within de AI field. At the same time, within any of these domains often is necessary to handle an important set of concepts tools and techniques comming from a variety of disciplines, such as logics, psichology, economy, operational research, system theory, linguistics, and so on. This has ressulted on the actual status of the AI as one of the most extensives, interrelated and interdisciplinaries fields of research.

Problem Solving

A particular task which has involved more interest at the moment, and one of the earliest developed is the problem solving. In spite of, we have not yet succeed in the development of a general problem solver machine. Among those early attempts to build a general purpose problem solver, we can see Newell, Shaw and Simon's GPS (General Problem Solver) (see Newell and Simon, 1962), which in spite of its own name and the efforts of its builders, never would get this purpose, showing as its application domain was extended a significant decrease in its efficiency.

However, an important number of specific problem solvers have been developed with certain succes. These problem solvers have proved their ability and consistency in solving problems into a limited domain. With them, an important body of knowledge has emerged, whose aim is to resume and make a good use of a whole set of ideas used to develop them: this body of knowledge is so-called Heuristic Search Theory or, from a more wide perspective, Search and Problem Solving theory.

Heuristic Search

A substantial part of problem solving programs in AI, esentially uses a kind of information called "heuristic", to manage and control the searching process of the problem solution. This is possible because almost in all the human tasks we can identify, after some analysis, a set of principles and empirical rules ("rules-of-thumb"), that helps in the searching effort reduction by drastically "prunning" the search space form those solution paths initialy considered as less promising. These rules are based on the previous knowledge about the domain of the problem we are trying to solve, which is acquired by experience: by solving in the past another problems like this or closely related with it.

As a consequence of the heuristic search paradigm that has been observed by the researches on automatic problem solving, within the AI field, the interest has been centred -since the early practical endeavours- on the developement of specific problem solvers, whose aim is to capture in some way, the empirical, particular and subjective expert knowledge used by the individuals when they solve problems in a certain domain. These specific problem solvers are called Expert Systems.

3. Knowledge Based Systems. Concepts and Applications

An Expert System (ES) is a computer system that solves problems in a particular domain with the accuracity and hability of a human expert. In the U.K., a wider definition has been generally adopted by most of computer scientists. The Expert Systems Group of Computer British Society has developed the following definition of an ES:

"An expert system is regarded as the embodiment within a computer of a knowledge-based component from an expert skill in such a form that the system can ofer intelligent advice or take an intelligent decision about a processing function. A desirable additional characteristic, which many would consider fundamental, is the capability of the system to justify, on demand, its own line of reasoning in a manner directily intelligible to the enquirer. The style adopted to attain these characteristics is rule based programming".

This definition can be considered as a functional one, that is, by the task involved. Another definition less extended but more correct form a theoretical point of view is the following one: an Expert System is a computer system in which specific knowledge to tackle problems and the procedural knowledge that makes possible to solve problems manipulating these specific knowledge, are clearly differenciated.

Therefore, in an ES specific knowledge and solution procedures are, in some way, independents and even interchangeables, that is: we can change the problem domain by only changing the specific knowledge but maintaining the solution procedures. Due to its structural approach, expert systems have been labeled also as Knowledge Based Systems (KBS).

Components

Due to the different degrees of analysis, a single scheme does not exist, but there is a certain agreement related with tree basic compmnents (see Fig. 1):

- The knowledge base. This component is integrated by both kinds of knowledge we saw before: specific knowledge, which usually is enclosed in the way of facts (concepts, terminology, concept relations and so on), and the procedural knowledge, which usually is embodied in the form of rules and determines the real intelligence of the system, its expertise and its real utility.

- The inference engine, is the one who realizes the whole process of problem solving activity and controls all the system. It begins the searching process of the solution under request, starting from the data or information provided by the user, accomplishes the successive transformations in the data using the information included in the knowledge base, and stops all the process when a solution arises.

- The situational model, also called working-memory. It contains the data and answers provided by the user, but also the intermediate results or deductions the system is generating by the solution process. This model represents the problem solution's actual situation all the time.

Another components which have been suggested inside the arquitecture of a KBS are:

- The knowledge adquisition subsystem.
- The explaining and justifying subsystem.
- The user interface, usually in natural language.
- The communication subsystem with another computer systems, such as a data base, or anyone.

If we remove the knowledge base from a KBS we can obtain an expert system shell, which is a powerful tool for the development of new expert system applications. This is a very interesting property of ES which reduces the development effort and has been an important reason of its extensive utilization; but more of this later.

The Application of Expert Systems

Considering the important amount of publicity surrounding knowledge-based applications, a surprisingly low number of real systems is in everyday practical use. A somewhat larger number has been at least field-tested, and a huge number of prototypes are being developed or has been tested only with toy data. Good overviews are provided by Fox(1984), Buchanan (1986) and Mertens et al. (1987). Most existing systems are exactly in those areas where early experiences already promised success: configuration of complex systems from predefined components, where many possible solutions exist; diagnostic applications, preferably in areas where not too many factors interact; and encodigns of formal rules and laws which are difficult to remember. A survey of some of these early systems is provided in Table 1, with some references to their main characteristics and utilization.

It was only recently that the first expert systems for real bussines applications appeared. Expertise in bussines domains differs in some ways from that in other areas, which has been an important difficulty in their development:

- It is frecuently distributed across multiple experts, especially when organizational rather than individual problems are involved.

- The rules of the game are changing frecuently; most business problems and opportunities arise whit the breakdown of accepted assumptions and rules.

- It requires constant scanning of various portions of the environment, thus the necessary integration with organizational or external databases as well as other information acquisition tools.

In all these applications, knowledge-based technology is intended to be considered as a component within a larger organizational or factory information system. In this sense, much effort will have to be made in the next future, to obtain the necessary integration of these components with another computer decision-aid tools, such as Decision Support Systems

(DSS), already working in the organization.

In general words, a DSS is a software package used to support decision making activities in situations where it is not possible or not desirable to implement a completely automated system, to carry out the overall process of decision making (Ginzberg and Storh, 1982). A DSS is a computer system capable of using sophisticated mathematical and statistical models -in the same way as data bases- in a real man-machine interface, to produce relevant informations to support the decision process in complex situations.

In this way, an interesting area of research in bussines domains will be the addition of knowledge-based methods to quantitative approaches: those specially studied by Operations Research. For instance, a scheduling algorithm can be enhanced by rules which represent constraints or desirable situations not easily represented by more conventional means. Much of the succes of approaches as the interactive multiple-goal programming is due to the user being able to supplement the underlying modelling with an appropiate knowledge or judgement.

Expert Sistems Tools

As many authors have pointed out, getting started in ES should not be equated with programming in an esoteric AI language (such as LISP or PROLOG) (O'Keefe et al.,1986). Useful systems have been produced in Pascal, FORTRAN and even BASIC, although the sense in using a traditional computer language has been questioned. Fortunately, there are now a large number of expert systems shells or packages available. Some of these are shown in Table 2. Most of these packages consist of a knowledge reppresentation language (K.R.L.), in which a knowledge base is encoded, and a special matching program that provides the inference mechanism.

An important factor when deciding upon a suitable package is how uncertainty is handled: many packages provide one or more inference mechanisms, normally based on Bayesian statistics or much more recently, in fuzzy logic, where uncertainty can be handled implicitly. A much narrower number of tools provide an induction facility, by which rules can be produced automatically from a set of examples. This can considerably improve the process of producing the knowledge base, in its speed and final consistency - fortunately much more than coding it from human experts. However, additional research on methods capable of realize these activities is needed.

CONCLUSIONS

Expert systems technology is begining to appear as an important and feasible alternative trend, for the developement of new decision support tools in business environments. The potential benefits of these systems comes from the explicitation of expert knowledge of the specialist in the organization, to its dissemination at low cost through the organizational structure. This will make possible expert advice and expert opinion in much more situations at all decision making levels within this structure.

The approach of the knowledge based tools is precisely compatible with the "bounded rationality" paradigm, in which are based the organizational behavior and management decision making of "administrative man".

To the development of those systems, a number of specialized generating tools are available. The choice among these depends on many factors, included the possibility of handle ambiguity, the need of system learn and interaction whith other computer support tools specially designed to carry out quantitative operations.

Despite the emergence of expert systems, the technology still is very young, and a number of developments are needed. Consultative systems are difficult to implement in many areas of management, since there are managers unwilling to approach to a keyboard, or to interact with a machine alone. Future systems, in these sense, will need to do better use of available data (for example the data contained in the central data base of the company), and will provide a better interface in natural language (in according to the expectations and developements of the next computer generation tools).

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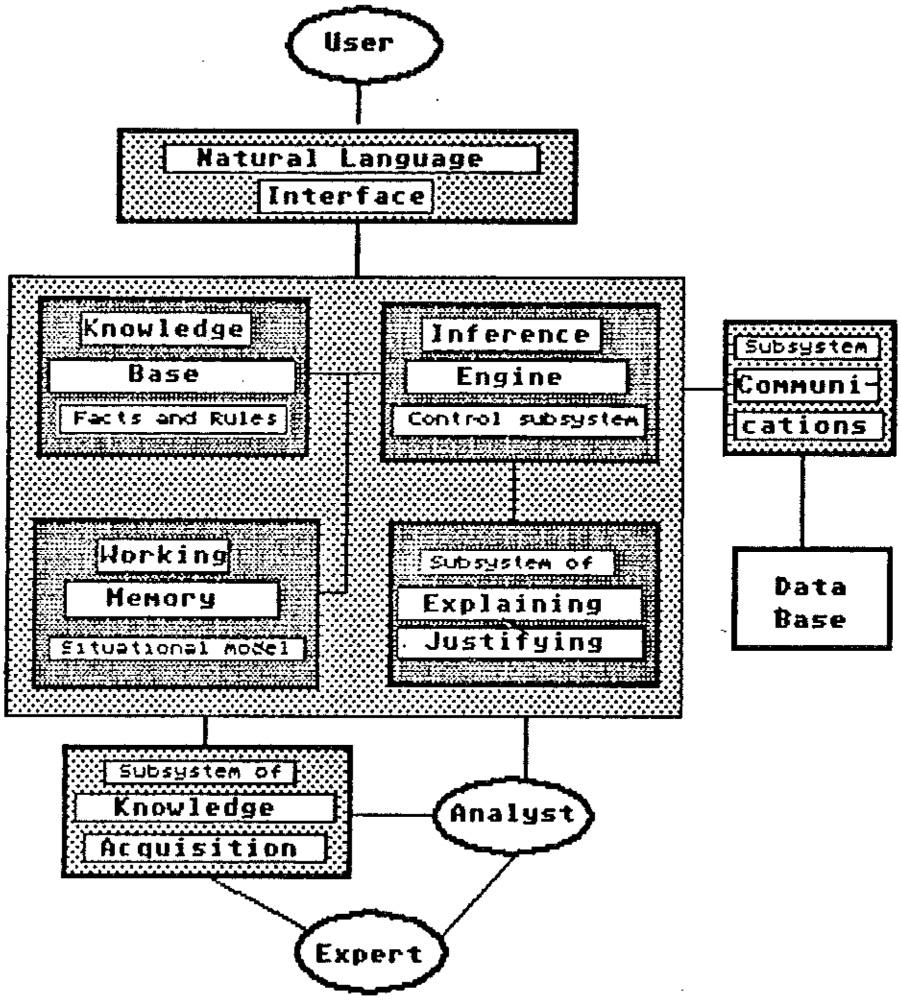

Figure 1. Main components of an ExpertSystem

Name	Task	Problem solving method	Remarks
DENDRAL	Identification of chemical compounds from mass spectra	Plan-generate-test with constraints based on heuristic information	Knowledge obtained through detailled collaboration with chemist Program performs well and is used widely.
MYCIN	Conducting medical consultation and therapy diagnosis	Rule-based with exhaustive search. Backward chaining and reasoning under uncertainity	The system performs well but is not in routine use. It provided important contributions to ES research through his model of reasoning.
PROSPECTOR	Probabilistic evaluation of sites for potential mineral deposits	Rule-like, semantic net and reasoning under uncertainity. Goal-directed search	High quality results in some applications. A very useful syste as a model for other experts.
MACSYMA	Performing complex symbolic computations	Early designed to use heuristic and opportunistic processes; later algorithmic methods	The system performs well and is widely used. It had a significant impact on development and application of symbolic manipulation processes.
GUIDON	Teaching medical knowledge to students	Rule-based with rules arranged in sets, opportunistic search control	The performance was encouraging and the system is undergoing a comprehensive design revision.
R1	Configuration of VAX-11 systems	Forward driven rule-based match-act cycle with hardly any backtraking	Program in routine use. It contains aproximately 2.400 rules distributed among 280 subtasks.
DIPMETER ADVISOR	Inferring subsurface geological structure	Production rules and algorithmic methods for pattern interpretation, forward-chaining inference, menu driven graphical user inerface	Knowledge obtained through interaction with an expert. Program operates on Xerox 1100 Scientific Information Processor.

TABLE - 1. A list of the best known expert/knowledge-based systems

Package	Machine type	Supplier	Knowledge rep.	Language	Uncertainty
ES/P Advisor	Micro	Expert Systems	Rule	Prolog-1	No
EXTRAN-77	Various	Intelligent terminals	Rule	FORTRAN	Yes
Expert-Ease	Micro		Tree	Pascal	No
RULEMASTER	UNIX		Rule	C	Yes
SAVOIR	Various	ISI	Network	Pascal	Yes
APES	Micro	Logic Based Systems	Rule	Micro-Prolog	No
LOOPS	Various	AI	Various (*)	Interlisp	Yes
ART	Symbolics	Feranbi	Various (*)	Lisp	Yes
KEE	Symbolics	Intellicomp	Various (*)	Lisp	Yes

TABLE - 2. Various Expert System packages / (*) Environment