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FRAMEWORK OF THE DECISION SUPPORT EXPERT SYSTEMS

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ABSTRACT

Recent advances in Artificial Intelligence have produced computer systems displaying human expert level expertise in several particular disciplines like medicine, organic chemistry, education, geological exploration... The Expert-System-Building systems became available and paper reviews prospects for their incorporation into DSS proposing Mixed Binary Linear Goal Programming (Discriminative Optimization in particular) as a framework for Decision Problems.

LIST OF KEY TERMS

Consultation System, Decision Support Framework, Decision Support System, Discriminative Optimization, Expert System, Expert System Building System, Goal Programming, Knowledge Engineering, Linear Goal Programming Decision Models, Management Information System, Mixed Binary Goal Programming,

PREFACE

The following paper was inspired by inherent shortcommings of the OR methods when applied to a broader field of Decision Support. Despite constant, respectable progress, the existing OR methods and techniques are confined to very usefull, but relatively low key routine decisions (especially in operational control and planning) and many of the most important decision problems escape OR. Therefore a substantial gap exists between what OR can do and what it is expected to do and extrapolation of existing trends doesn't provide much hope that this gap can be bridged adequately in near future. The realization of an unpenetrable barrier and resulting frustration is more and more apparent in OR literature. Search for a remedy to that situation focused recently on Expert Systems who employ entirely different principle to arrive at solutions. Expert Systems can be the best, available today, answer to the shortcommings of OR.

The purpose of the paper is twofold; Firstly it is to alert the readers to the emergence of Expert System technology, and to discuss advantages as well as shortcommings contrasting it with classical OR methodology. Secondly, to explore the possibilities of incorporation of Knowledge Engineering technology into Decision Support Systems.

To serve its purpose the paper is divided into two parts; one describes the state of Expert System technology presenting its strenghts and limitations. Second part discusses Decision Support framework concentrating on showing the existence of decision problems that won't be ever adequately supported by OR as we know it today, hypothesise on a form a future Decision Support Expert System (DSES) - combining Quantitative Methods with Knowledge Engineering - will take, and advances a proposal to use a particular Quanitative Method - Discriminative Optimization (DO) - as an "Optimization Engine" of a DSES.

INTRODUCTION

The Expert Systems have gained recently some publicity solving real-life problems with an impressive effectiveness. There are Expert Systems that diagnose different types of diseases or aid geologists in discovering mineral deposits. In doing so the Expert Systems displayed the ability to process large quantity of experimental data, meticously applying complex decision procedures. At times the performance of Expert Systems was comparable or even superior to that of human experts, especially when the decision situation was routine and involved complicated set of rules depending on multitude of decision variables, mostly because they did not miss unlikely possibilities and considered much larger set of possible solutions.

The questions accessed in the following presentation are; Can an Expert System be usefull in Business Decision Making? Can Expert Systems be beneficially incorporated into Management Information Systems or Decision Support Systems?

The answer to those questions is a positive one since, in short, Expert Systems in a way complement Operations Research (OR) methods. The OR methods, and employing them Information Systems, are best suited for structured decision problems, and their application area gradually expands onto problems presently considered to be semistructured /1/. It is widely believed in the Information System field, that decisions with the greatest payoff for the organization are of unstructured nature /36/. Expert Systems are designed for unstructured decision situations, and they can serve as a structuring tool. Therefore incorporation of Expert Systems into Decision Support Systems is potentially beneficial and should produce a decision aid of a superior quality /46/. There are indications that Mixed Binary Linear Goal Programming - and Discriminative Optimization in particular - could be a method comprehensive and powerfull enough to be used as the optimization problems formalism.

Expert Systems are commonly described as computer systems that:

- o Aid solution of complex, real-world problems in specific specialties; scientific, engineering, or medical.
- o Use large bodies of domain knowledge - expertise, in form of facts and procedures, that are considered by experts usefull in solving typical problems in respective domain.
- o Transfer necessary kinds and quantities of knowledge from experts to Artificial Intelligence systems.

EXPERT SYSTEMS

Since the very beginning of computers in late 1950s, there were numerous attempts at development of computer programs that would perform some 'intelligent' operations simulating intellectual functions of humans/2,3/. Those early AI systems were constructed based on domain specific knowledge representation schemes and solution procedures. Those early AI Systems explored practically all areas of todays Artificial Intelligence and paved the way towards Expert Systems.

A short review of Early Artificial Intelligence Systems includes;

GPS General Problem Solver; by Newell, Shaw, and Simon (1957) /41/ It implemented the heuristic search of a state-space representation of the problem to be solved.

The Geometry Theorem Prover; by Gelentner (1959)/27,28/. Was famous to discover a high-school level theorem in plane geometry.

SAINT Symbolic Automatic INTegrator; by Slagle (1961) /59/ Solved elementary symbolic integration problems at about the level of a college freshman.

Checker Program; by Samuel (1963) /53/ Experimented with computer learning on two computer checker programs playing with each other.

SAD-SAM; A Natural Language Processing System; by Lindsay (1963) /34/ It accumulated English sentences about kinship relations and answered simple questions about facts it stored.

The Expert Systems, in contrast to the early Artificial Intelligence Systems are aimed at domain independence, i.e. their software contains no, or little of implicit knowledge about problem domain. The domain knowledge is stored in Knowledge Bases (Data Bases) in a domain independent fashion. A typical Expert System operates on hundreds objects, using hundreds rules at speeds of hundreds of thousands of LIPS (Logical Inferences Per Second).

Expertise, the content of an Expert System, is usually interpreted as a vast, task-specific knowledge acquired from training, readings, and experience of many hundred practical cases. Following types of knowledge constitute the expertise:

* facts about domain,
* hard-and-fast rules and procedures,
* heuristics for given problem situations,
* global strategies,
* theory of the domain.

As functions of an Expert System there are mentioned:

* solution of fuzzy, nonnumerical problems,
* representation and utilization of knowledge at different levels of abstraction; starting, for example, from project level through corporate strategy level,
* Question/Answering interaction in Natural Language,
* Consultation and Explanation enabling manager (user) to understand preassumptions and the process leading to the answer,
* utilization of heuristics, informal, judgmental knowledge of an application area,
* employment of the problem solving expertize;
  how to solve problems effectively/efficiently?
  how to plan steps in solving a complex problem?
  how to improve performance?

Much more information on Expert Systems can be found in /3,40/.

From among the miriad of Expert Systems currently in existence, the following brief review presents their most typical application areas;

Chemistry;

DENDRAL	interprets mass spectrograms /9,33,35/.
CRYSTALIS	interprets protein X-ray crystalograms /22,23/.

Medical diagnosis;

MYCIN	diagnosis and therapy for infectious diseases /54/.
PIP	kidney diseases diagnosis /42,60,61/.
PUFF	pulmonary function diagnosis /32/.
HEADMED	psychopharmacology diagnosis /31/.
VM	intensive care monitor /24/.

Assisted learning;

WEST	guided discovery learning /10/.
BUGGY	student misconception determination /5,6,7,8/.

Other;

The Programmer's Apprentice	automated programming /51,52,55,65/.
MACSYMA	algebraic formula manipulation /37,39/.
RENDEZVOUS	Natural Language Data Base interface /11/.
PROSPECTOR	hard-rock exploration assistant /18,19,20/.

CONSULTATION SYSTEMS

The Consultation Systems are a higher stage in Expert System development. In addition to just solving complex problems requiring application of an extensive expertise, the Consultation Systems can explain their behaviour answering interactively following types of questions;

* how certain conclussion was reached?
* why a particular question was asked?
* what is the plan for reaching the solution, for example; what remains to be established before a diagnosis can be determined?

Consultation Systems facilitate the transfer of expertise from experts to a computer system and make sure the knowledge accumulated presents a consistent system of concepts. The ability to trace responsibility for conclussions to their sources is crucial in the transfer of expertise from expert to a program, since the expert should be able to assign credit or blame for erroneous conclussions to missing or incorrect knowledge-base elements. Similarly such function is necessary in any learning if a program is to be able to analyse the reasons for its success or failure. The strategy used by a consultation system for knowledge accumulation and concept formation is a part of the Meta-knowledge.

First Consultation Systems were developed as user-friendly front-ends to existing Expert Systems; those are for example:

THEIRESIAS the interface to MYCIN /13,14,15,16/.
Meta-DENDRAL Automatic Concept Formatter for DENDRAL /9,35,38/.

Expert Systems being developed recently have explanation facilities build into the initial design. Such are for example:

PROSPECTOR hard-rock exploration /18,19,20/.
INTERNIST diagnosis of internal disfunctions /43/.

EXPERT SYSTEM BUILDING SYSTEMS

The Expert System Building Systems (ESBS) are a most advanced form of Expert Systems and they are, in a sense, Meta-systems. ESBS can be characterized as software packages enabling development of an Expert System in any domain without necessity for software development. The primary function of Expert System Building Systems is extraction and transfer of the knowledge from human experts to be preserved in a computer system. Expert System Building Systems are usually implemented as Consultation Systems without domain Knowledge Base. The following are representative examples;

EMYCIN knowledge acquisition module of MYCIN /64/.
IRIS tool for building and experimenting with medical Expert Systems /62,63/.

The concept of KIPS (Knowledge and Information processing System) is also worth a mention. The KIPS is a part of Japanes V-th generation project planned for 1990s. It is to be fully domain independent, it should operate on hundreds of millions of objects (ca. the volume of Encyclopedia Brittanica), it should be applying tens of thousands of rules, at speeds of tens of millions LIPS /25/.

The synthetic structure of an Expert System is presented on Figure 1. It contains following modules:

DATA BASE storing facts used by Knowledge Base system.
KNOWLEDGE BASE containing "hard-and-fast" rules and procedures, heuristics for particular problem situations (about how to use, and when not to use given facts), global strategies and theory of the domain. The knowledge, not merely facts, is the primary material of Expert Systems.
KNOWLEDGE BASE MANAGER coordinating the Knowledge Base, Knowledge Acquirer and Inference Engine modules.
INFERENCE ENGINE a deductive program making conclussions from the facts present in the Knowledge Base. Usually it is a Resolution Principle based Theorem Prover written in LISP or PROLOG.
KNOWLEDGE ACQUIRER an inductive inference program guiding interaction with the expert.
NATURAL LANGUAGE INTERFACE provides user friendly communication with the human expert.

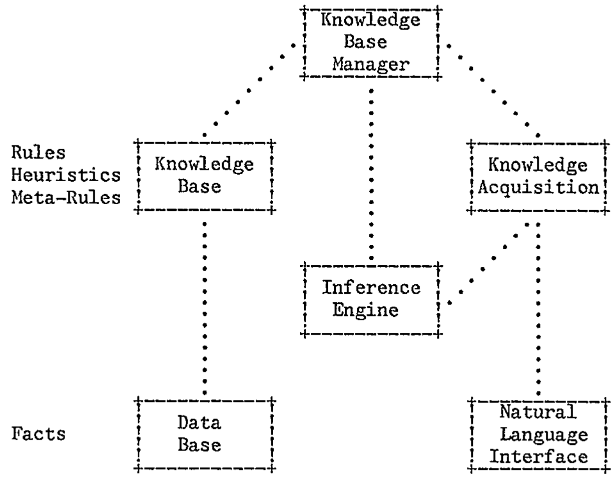

Figure 1: Structure of an Expert System

The opinion of AI experts asserts that 'Expert Systems come of age' /17/ and, according to E. Feigenbaum, 'AI is finally ready for market'.

KNOWLEDGE REPRESENTATION

Commenting on Knowledge Representation schemes employed in Expert Systems it has to be noted that the First Order Predicate Calculus (FOPC) is the common denominator there, eventhough it is rarely used explicitely in it's mathematical form. Only few, mostly early systems, use other, usually domain specific knowledge representation schemes - like procedural representation or semantic networks /2,40/ - and even those schemes can be ultimately presented as equivalent to FOPC.

The most popular, special form of FOPC formulas is known as a production. A production is formed out of a list of conditions followed either by list of actions to be taken or a list of conclussions to be infered when all conditions from the list are met. An illustration of production is presented on Figure 2;

Conditions THEN Actions
Conditions THEN Conclussions

Example:

```
OVER_CREDIT_LIMIT(APPL)    AND
90_DAYS_DEBITS(APPL)                THEN
REFUSE_LOAN(APPL)          AND
NOTIFY_MANAGER(APPL)
```

Figure 2: Productions knowledge representation

The productions with a likelyhood measure assigned to them are used to model nondeterminism in a decision situations. A likelyhood is assigned to facts, rules, and conclussions in, among others, MYCIN, and PROSPECTOR.

In the above framework the facts are represented as the productions of a particular form , i.e. lists of conclussions not preceeded by conditions. The Knowledge Base module employs a standard DBMS to implement given Knowledge representation scheme.

The knowledge representation schemes are being utilized to model abstract concepts operated on by Expert Systems. Most developed of them are /2/;

FRAMES which are data structures designed to represent a large, well-coordinated body of knowledge gathered from previous experience and to be used to interpret new situations.

SCRIPTS a Frame-like data structures designed to represent time sequence of events. A common knowledge about a movie theater can serve as an example of a Script. Attending a movie theater we never have been in before we still have quite accurate idea about elements we are about to find there; cashier, refreshment stand, restrooms, viewing hall; as well as the most likely order in which events are to take place; buy a ticket, buy some popcorn, select a seat, etc.

The Expert Systems with explanation facility (Consultation Systems) can be characterized by the degree to which their reasoning and manipulation of the expertise, resembles methods used by human experts. It can be noted that earlier systems used representation methods and reasoning different than those of human experts while more recent systems emulate human concepts and reasoning. The explanation function can be therefore implemented in a more natural way in the later systems, while it requires a special, additional module to be added to the earlier systems.

DENDRAL and MACSYMA are examples of systems operating with opaque, both representation method and reasoning; mainly due to the fact that methods used by chemists and matematicians respectively, were incomplete.

MYCIN and PROSPECTOR use right concepts and explanations but opaque reasoning.

PIP and INTERNIST emphasise similarities of their diagnostic procedures to these of a physician.

TYPES OF REASONING IN EXPERT SYSTEMS

Several types of reasoning about the knowledge are being distinguished in the literature of Expert Systems. They range from purely deductive reasoning that is best handled by computer systems to different types of inductive reasoning that continue to be difficult to formalise.

FORMAL REASONING involves syntactic manipulation of data structures to deduce new facts following prescribed rules of inference. Mathematical Logic is the archetypical formal knowledge representation, and predicate calculus an effective deductive technique.

PROCEDURAL REASONING uses simulation on models of the domain to answer questions and solve problems.

REASONING BY ANALOGY seems to be a very natural mode of thought for humans but, so far, difficult to accomplish in AI programs. The idea is that when you ask question: What are the working hours of an accountant from C+L? the system might reason that accountants and internal auditors in C+L are of comparable job category, and I know that internal auditors in C+L work 9 to 5, so accountants probably work 9 to 5 too.

GENERALIZATION AND ABSTRACTION are also natural reasoning processes for humans that are difficult to capture well enough to implement efficiently in a program. If one knows that internal auditors in C+L work 9 to 5, that accountants in C+L work 9 to 5, and that system analysts in C+L work 9 to 5, eventually one might conclude that ALL nontechnical personell in C+L works 9 to 5.

META-LEVEL REASONING is demonstrated by the way one answers the question: What is my boss's telephone number? It can be reason that "if I knew my boss's telephone number, I would know that I knew it, because it is a notable fact". This involves a "knowledge about what you know", in particular about the extent of your knowledge and about the importance of certain facts. Recent research in psychology and AI indicates that meta-level reasoning may play a central role in human cognitive processes and it is therefore an object of interest of machine learning.

LIMITATIONS

Current Expert Systems operate on Knowledge Bases containing hundreds of rules - MYCIN 450 productions. Despite a moderate size of the Knowledge Base some of the Expert Systems are able to display decision making performance at times at least comparable to that of a human expert.

The most immediate conclussion that can be drawn from that observation is the few hundreds of productions is a measure of the ammount of knowledge a single human expert can effectively use. An idependent estimates - pointing at the same order of magnitude - are provided by recent research on cognitive complexity. It indicates that existing Expert System technology is just sufficient to model decision processes of a single Decision Maker, be it a manager or a negotiator.

Conversely, more comprehensive and integrated applications like Knowledge Base of corporate policies and strategies might still await adequate technology and - even more importantly - adequate methodology. It is observed that formalization of an expert knowledge in an consistent manner is a task of a rapidly increasing difficulty as the number of rules increases. It is also noted that development of a Knowledge Base while consulting two experts simultaneusly is next to impossible.

The existing technology makes it relatively easy to store new facts and rules. Making sure the acquired knowledge is consistent - not to mention valid - is a much more consuming task. Maintenance of future Knowledge Bases accumulating expertise of many independent individuals will require entirely different verification methods than those practiced today and a hardware of the V-th Generation performance.

DECISION SUPPORT FRAMEWORK

Regarding the other part of the topic; the Decision Support Systems, lets start with the simplified DSS framework presented on Figure 3 /4/, originated on that of Gorry and Scott Morton /29/ and based on decision cycle model of Simon /56,57,58/ and managerial decisions classification of Anthony /1/.

DS Framework	Operational Control	Management Control	Strategic Planning
Structured Programming	Accounts Receivable	Production Scheduling	Financial Management
Semistructured Programming	Joint Costing	Plant Location	Mergers and Acquisitions

Figure 3: Decision Support Framework

The scope of the Figure 3 reflects the fact that most of the existing Information Systems have attacked problems in structured, operational cell. These problems are similar in many organizations and are among the most easily understood. Symptomatically, problems most important to an organization are unstructured in nature.

Unstuctured Programming can be characterized as follows /4/;

- o solution objectives are ambiguous, numerous and not operational,
- o the process required to achieve an acceptable solution can not be specified in advance,
- o it is difficult to determine, either in advance, or after the fact, which steps are directly relevant to the quality of a decision.

When we consider that every problem, when faced for the very first time, appears to us as unstructured, it is evident that a substantial gap exists in the scope of Decision Situations covered by DSS. Only after some experience is accumulated through practice, a Decision Maker develops workable decision schemes, a structure is imposed on previously amorphic decision situation; the problem becomes semistructured and the Operations Research techniques can provide an assistance /1/. Expert Systems seem very well tailored for the role of a helper in structuring new decision situations, organizing acquired experience, and isolating subproblems suitable for OR methods.

The fact that Decision Support Systems are still far from the state of a perfect decision tool is reflected also in the practice of interfacing the Decision Maker with a DSS through assistants and staff personell, Figure 4, who translate Decision Makers' perception of the decision problem into commands executable by DSS, and interpret obtained reports. Such an extended DSS gains much of its power and flexibility from the human intermediary. Effective communication between manager and a computer tool is vital since it is observed that the decision makers expect to excersise direct, personal control over their support system /21/, eventhough they not necessarily need to operate the DSS personally /30/. Expert Systems can be a remedy in that area too, taking a part in interfacing the Decision Maker with computer Decision Support System.

```
+----------+        +-----------+         +----------+
!          !        !Assistants !         ! Decision !
!  D S S   !--------!and staff  !---------!  Maker   !
!          !        !           !         !          !
+----------+        +-----------+         +----------+

 Data               Principles            Expertise
 Models             Strategies            Unquantified
                    Codified                 Knowledge
                      Knowledge
```

Figure 4: The Decision Maker - DSS interface

GENEALOGY OF DECISION SUPPORT SYSTEMS

There exist several contradictory opinions about the relation between Management Information Systems and Decision Support Systems. According to the view favoured in this paper, the progressive sequence of Management Systems consists TPS, MIS, DSS /4/.

TPS — Transaction Processing System; performs pure Data Processing for gathering, updating and posting information. There is little or no managerial decisions; most decisions are clerical and routine.

MIS — Management Information System; have predefined data aggregation and reporting capacities, and still unchangeable decision space. The structure of problems assisted by a MIS is fixed; administrative control is the typical application area, and a DBMS constitutes an important component.

DSS — Decision Support System; an extensible system that can support ad hoc decision modelling in evolving decision space. Structure od problems assisted by DSS is flexible. The typical applications of DSS are in the area of administrative and strategic planning.

Lets extrapolate the above trend on decision systems with knowlegable components, and name them DSES (Decision Support Expert Systems). The DSES would;

- o operate on explicit knowledge stored in a Knowledge Base,
- o interface with the Decision Maker in Natural Language,
- o choose proper QM technique based on obtained problem description, data, and knowledge available regarding the decision situation,
- o create a quantitative model of the decision situation,
- o present and explain the solution to the Decision Maker.

It can be expected that a DSES would not be dependent on the problem structure, and would be able to adapt itself to new types of problems. The semi- and unstructured problems would be assisted, and the application area would include strategic, large scale, and long-term planning.

The most prospective future applications of a DSES can be expected in semistructured areas like;

- Accounting; audit, CPA expertise,
- Margers and Acquisitions,
- Law; Tax Law in particular,
- Career Path Management,
- Negotiations; multiparty and multiissue in particular,
- Marketing; Sales,
- Long-term, Large-scale Strategic Planning

The most immediate results can be expected though in modeling and explaining of the decision processes of a single Decision Maker as well as transferring corporate wisdom codified in intraorganization practices, policies and strategies into computer Expert Systems.

LINEAR GP MODELS AS KNOWLEDGE REPRESENTATION SCHEMA

A far prototype of the above mentioned type DSES can be seen in TIMM (The Intelligent Machine Model) /26/ which interactively identifies the decision domain, learns and perfects decision rules and makes decisions in new situations. The real advent of Expert Systems in Decision Support is unlikely however until the optimization models are incorporated.

Looking for a most prospective kind of decision models, the linear models immediately come to the attention. Among those the Linear Goal Programming models are most capable due to the employment of the goal hierarchy which allows powerfull extentions to the optimization model formulation including - among others - piecewise approximations of nonlinear constraints and objective functions /47,50/. Further yet, the Mixed Binary Goal Programming problems (dealt with comprehensively by Discriminative Optimization /44,45/) offer greatest modelling power.

Discriminative Optimization is designed as an uniform framework for formulation of optimization problems arising in Decision Support. The principle of the method is in a two level modelling consisting a main model directly corresponding to the decision situation and a LGP model generated from it. The main model is parametrized by several discrete factors and accordingly is the corresponding LGP model. A LGP solution is translated back and presented to the decision maker in terms of the main model. The actual details of the solution procedure are screened from the user of the method who operates on an outside model translatable into a Linear Goal Programming problem.

Discriminative Optimization Problem is formulated as follows /44/;

There are given:

Non empty set $D \subset \{0,1\}^k$

Non-empty, compact set $X_d \subset R^n_+$, $d \in D$

Continous mapping $H_d : R^n_+ \longrightarrow R^s_+$, $d \in D$

Lexicographical order relation "$\leq_d$" on R^s_+,

Determine:

The set;

$$X_s = \left\{ x \in X_d \;\middle|\; d \in D,\ H_d(x) = \min_{d' \in D}\ \min_{x' \in X_{d'}} H_{d'}(x') \right\}$$

The set D represent binary decision variables or the set of boolean conditions associated with a discrete (integer) fragment of the decision model. The set X_d is a feasible set that depends on the state of the discrete submodel. The goal achievement function H_d is also parametrized by binary characteristic. A lexicographical order "$\leq_d$" accords multiple, uncommeasurable objectives, in a way specific to Goal Programming Methods. The optimal set X_s contains all those feasible solutions that present best underachievement measures (in a sense determined by order "$\leq_d$") under any selection of the binary characteristic $d \in D$

The set

$$D_s = \left\{ d \in D \;\middle|\; \min_{x \in X_d} H_d(x) = \min_{d' \in D}\ \min_{x' \in X_{d'}} H_{d'}(x') \right\}$$

the set of binary characteristics allowing optimal goal achievement is another result of the simplex-based solution process.

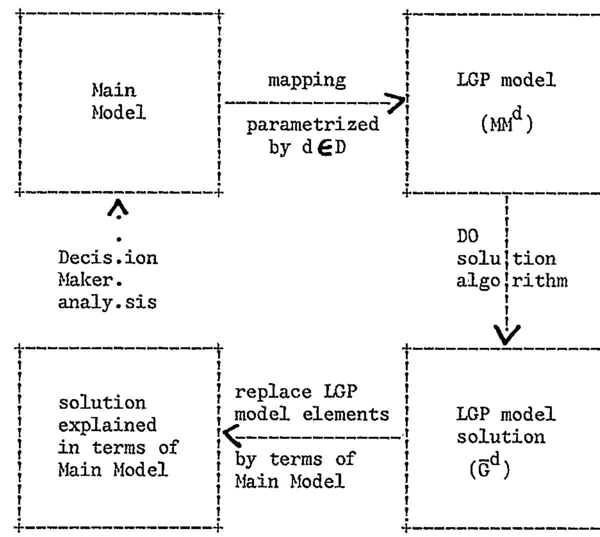

Figure 5: Decision Making with Discriminative Optimization

From the information point of view a Discriminative Optimization problem can be vieved as a set of two data bases of a kind, with LGP model being one data base generated from data describing the main model. The main model in turn can be viewed, according to approach proposed by Aggregative Goal Programming /49/ for example, as an abstraction or User View of a larger data base containing all knowledge available to the organization (decision maker) about decision situation. A part of that knowledge, corresponding to current information needs is being extracted in a form of a cohesive main model, corresponding LGP model solved, and optimal solution presented in terms of main decision model.

The flavour of model generation specific to Discriminative Optimization and similar methods can be illustrated on the following, simplified example of the Network LGP Problem /48/ since many decision problems involve a flow network, more or less explicitely expressed. Those are - for example - decision situations with transportation or technological processes. In many cases network part of a problem constitutes over 90% of the model size. Therefore LGP problems built around an explicitely defined flow network have a distinct practical significance.

The network LGP problem contains: flow-network description, a set of structural criteria and constraints implied by the network, goal hierarchy that includes - as a highest priority goal - the demand that the network structure be preserved, and all of the decision maker goals.

Let $N = \{n_1, \dots, n_z\}$ be a set of nodes and $E \subset N \times N$ a nonempty partial order relation. The pair $F = (N,E)$ is a graph and ordered pairs $(n_r, n_s) \in E$ are graph edges where n_r is the predecessor and n_s the successor. An edge (n_r, n_s) will exchangeably be de-

noted by $n_r \longrightarrow n_s$, and $\overset{+}{\longrightarrow}$ will stand for transitive closure of the relation E.
Then $N_n = \{n' \in N \mid n \overset{+}{\longrightarrow} n'\}$ will be the set of nodes reachable form the node n. The set of input nodes N_I (or sources) is defined as follows;

$$N_I = \{n \in N \mid \forall_{n' \in N} \; (n',n) \notin E\} \quad (1)$$

Similarly the set of output nodes N_O (or sinks) is defined by;

$$N_O = \{n \in N \mid N_n = \emptyset\} \quad (2)$$

The network LGP problem can be therefore described through a list of following elements;

- flow network F that is a connected, acyclic graph corresponding to a single medium, nonretaining flow network with one input and one output nodes,
- edge decision variables $x_{rs} \geqslant 0$ for $e_{rs} \in E$
- set of constraints and criteria generated by given flow network F;

structural equations;

$$\sum_{e_{pr} \in E} x_{pr} - \sum_{e_{rs} \in E} x_{rs} + n_i - p_i = 0 \quad (3)$$

$$\text{for } i = 1,2,\ldots,\bar{N} - \bar{N}_O - \bar{N}_I$$

- constraints on flow through sources and sinks;

$$\sum_{e_{rs} \in E} x_{rs} + n_i - p_i = U_r^I \quad (4)$$

$$\text{where } n_r \in N_I,\; i = \bar{N} - \bar{N}_O - \bar{N}_I + 1,\ldots,\bar{N} - \bar{N}_O$$

$$\sum_{e_{rs} \in E} x_{rs} + n_i - p_i = U_s^O \quad (5)$$

$$\text{where } n_s \in N_O,\; i = \bar{N} - \bar{N}_O + 1,\ldots,\bar{N}$$

- network edge capacities

$$x_{rs} + n_i - p_i = U_{rs} \quad (6)$$

$$\text{where } e_{rs} \in E,\; i = \bar{N}+1,\ldots,\bar{N}+\bar{E}$$

- remaining criteria - some of them defined using network edge attributes;

$$f_i(x) + n_i - p_i = b_i \quad (7)$$

$$\text{for } i = \bar{N} + \bar{E} + 1,\ldots,m$$

- set of goals;

minimal flow requirement;

$$G_1(\bar{n},\bar{p}) = \sum_{i = \bar{N} - \bar{N}_O - \bar{N}_I + 1}^{\bar{N}} g_i(n_i,p_i) \quad (8)$$

network structure preservation requirement

$$G_2(\bar{n},\bar{p}) = \sum_{i=1}^{\bar{N}-\bar{N}_I-\bar{N}_O} (n_i+p_i) + \sum_{i=\bar{N}+1}^{\bar{N}+\bar{E}} p_i \quad (9)$$

the decision maker goals - starting with constraints;

$$G_k(\bar{n},\bar{p}) \quad k = 3,4,\ldots,s \quad (10)$$

$$\text{where } x,\bar{n},\bar{p} \geqslant 0$$

The above formulated LGP network problem is evidently equivalent to a LGP problem with most of constraints and the most priorited goal function generated by definition of the flow network F, and therefore it can be solved by a LGP algorithm - like Discriminative Optimization algorithm /44,45/ - adapted to operate with network descriptions. Under presented approach the Decision Maker manipulates network model of the decision situation and his nonnetwork objectives, but he doesn't have to deal with details of the LGP model. Therefore;

* the description of the decision situation is greatly clarified due to separation of different model components,
* model description corresponds closer to the merit of the decision situation,
* volume of model information that needs to be entered to the computer is significantly reduced by the ammount of structural equations and constraints.
* the details of Main Model are filled automatically by the DSES from the current content of Knowledge Base according to scope of the decision situation chosen by the Decision Maker /49/.

CONCLUSSIONS

Presented paper attemptes to illustrate following theses;

- Proliferation of Expert Systems is observed and expected to intensify in near future,
- There are problems in Business Decision Making poorly assisted by present OR and Expert Systems provide a more adequate solution.
- Expert System technology is on the treshold of marketability,
- Expert System Building Systems provide a number of important and attractive software features in a ready to use packages. Those are;
  - Natural Language Interface,
  - User Friendliness,
  - Knowledge Acquisition Mechanisms,
  - Inference Engine, etc.
- As the Expert System technology matures, a standarized "Knowledge Management Systems" will appear, analogous to today's DBMS.
- The mixed binary Goal Programming method is well suited for the role of optimization framework in the DSES.

It seems therefore that necessary preconditions for merger of Expert Systems into DSS are met, and Decision Support Systems in close future will present a qualitatively superior decision aid.

Analysis of presented trends, as well as the Japanes V-th generation projects indicates that computer systems operating on knowledge as well as on data are likely to bring about a second computer revolution when yesterdays "Fast Number Crunchers" will begin to Learn, Make Judgements, Reason, and take an increasing role in Decision Making - eventhough we might be just at the beginning of the road.

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