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PROBLEM OF MAN-MACHINE INTERACTION IN DECISION SUPPORT SYSTEMS

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Given the variety of definitions of decision support systems, common to all of them is that these are systems whose basic elements are computers and decision makers. Rapid development of computers, emergence of microprocessors and flexible, rather sophisticated programming languages provide wide opportunities for their application to decision problems. But how these opportunities are exploited, to what extent they can really be helpful in decision making considerably depend on the arrangement of man-machine interaction, on the account taken of specificities and limitations of the human information processing system.

The paper classifies different decision making problems wherein decision support systens were used. An analysis is performed for the major classes of the problems relative to commensurability of decision making procedures to the capabilities of human information processing system. Primary information processing operations, whose analysis allows to evaluate validity of respective decision support systems, are identified.

PROBLEM CLASSIFICATION

There is something fuzzy, insufficiently explicit in different definitions of decision support systems. According to some definitions [2] these are universal expert systems that were generally dealt with by specialists in artificial intelligence.

According to another definition [24] these are improved computer-based decision making systems (including shared ones).
Given all the definitions and interpretations of both the content and the application areas of the systems, there is no arguing that this branch of research covers systems whose major elements are computers and decision makers. Fast development of computers, emergence of microprocessors and flexible, rather sophisticated programming languages offer considerable opportunities for their application in decision problems. But the ways the opportunities are used, the extent to which they can actually be helpful in decision making considerably depend on the arrangement of man-machine interaction, on the account taken of specificities and limitations of human information processing system.
The research conducted in recent years indicates that human capabilities in complex decision problems are rather limited [21]. It is not always easy to distinguish the limits as people adapt to complex problems, simplify them thereby changing their content [6], employ different heuristics [19]. Nevertheless, there are a lot of factors testifying to the fact that such constraints do exist, and that they considerably affect solution of different, including very important problems [6,15].
A question arises as to what assistance the computer can render to decision makers. In analyzing different existing man-machine decision making systems one can distinguish two basic functions performed by computers:

- assistance in structuring the problem, in building a model, in specifying one's "world outlook" (system of criteria, set of alternatives, ets.);
- assistance in eliciting preferences within the framework of the assigned structure (determination of criteria relations, of alternative estimates, etc.).

In order to study the ways the functions are performed, it is necessary to classify decision making problems.
First of all, decision making problems are generally defined as ill-structured problems (according to H.Simon's definition [20]). It is worth noting that the operations research problems [25] that may have an objective model with a single (and obvious) quality criterion, do not refer to decision making problems. The latter are characterized by uncertainty which does not allow to find a unique, objectively best decision. It is this uncertainty that makes it

necessary to employ, in solving the problems, the decision maker's preference policy (or that of a group of people).
Contiguous to operations research problems are decision making problems possessing an objective model, but solutions obtained with it are evaluated by several criteria. A good illustration is provided by the problems of multicriteria mathematical programming [23].
Besides, there is a wide range of decision making problems with subjective models where the latter is a totality of relations between the problem variables treated as criteria of decision alternative estimates.
The second line of proposed classification is the novelty of problems for a decision maker. We shall single out new, unique problems as well as the recurring ones.
And, finally, we shall divide the problems into the problems of holistic and criteria-experts choice [12]. Characteristic for the holistic choice problems is that the decision maker has a holistic image about a decision alternative, "gestalt". The latter is often much wider and more profound than its formal representation by a set of estimates by multiple criteria. Consumer choice is an example.
Problems of criteria-experts choice arise in cases when the decision maker does not have sufficient information for making up an idea about decision alternatives. The required information may be provided only by experts possessing special knowledge. The decision maker defines the composition of parameters (criteria) characterizing his attitude toward the considered problem, formulates a decision rule. An illustration of these problems can be provided by the choice of complex socio-engineering systems.
The proposed classification is presented in Table I. Its blocks contain examples of decision support models, letters in circles designate the method functions (A - structurization, B - preference elicitation).
Now we shall make several comments on the Table. It is worth noting also that the interactive DSS are generally not used for the recurring problems of criteria-experts choice with subjective models. Some other approach is used here: models are constructed with a view approximating human behavior. They are referred to as "Bootstrapping" [16].

Table I

		Criteria-experts choice	Holistic choice
Objective model with multiple criteria	Unique decisions Recurring decisions	Mathematical programming methods with multiple criteria [23] (B)	Multicriteria choice of machines constructions [22] (B)
Subjective model	Unique decisions	ZAPROS [13] (B) Keeney method [11]	MAUD [8] (A) (B)
	Recurring decisions	[16] Bottstrapping	(A) (B) Expert systems [4]

Note also that with holistic choice problems DSS are often employed both for structurization and preference elicitation. As for criteria-experts choice problems, structurization is as a rule carried out in advance and the systems are used for preference elicitation.

The psychological problems of man-machine interaction emerge in all decision making problems, included in Table I, when employing computers. They arise during construction of expert systems containing decision rules of the most experience decision makers. They emerge in the course of decision maker interaction with multicriteria objective models. They also appear while decision maker interacts with systems assisting him both in structuring his own policy (i.e. find its adequate representation by a system of criteria) and expressing his preferences in the form of a decision rule.

PSYCHOLOGICAL PROBLEMS OF FORMULATING MAN-MACHINE PROCEDURES WITH OBJECTIVE MODELS

There is a class of problems concerned with development of decision support systems that have been in the center of attention of scientific community for the last 10-15 years. These are multicriteria mathematical programming problems that are the topic of numerous books, overviews, proceeedings of conferences [17,23] The problem of multicriteria linear programming may be formulated as follows:

Find vector $X = (X_1, X_2, \ldots, X_n)^T$ belonging to domain

$$D = \{A\ x = b;\ x_i \geqslant 0,\ i = 1, \dots, n\}$$

where A - is pxn matrix, b is a p vector, and maximizing the totality of objective functions

$$C_k(x) = \sum_{i=1}^{n} Cik\ X_i,\ k = 1, \dots m$$

with the most preferable ratio between their values in the decision point. The last condition is understood as follows: in a variety of effective (Pareto optimal) decisions it is necessary to find X^* corresponding to the extremum of the a priori unknown utility function of decision maker.

Solution of the aforesaid problem is carred out through the application of a man-machine procedure that is a cyclic process of decision maker-computer interaction. Each cycle comprises two phases: the one of information analysis and intermediate decision making performed by an indifidual, and that of optimization exercized by computer.

At the analysis phase an individual assesses the preceding decision produced by computer and makes a judgement on its acceptability. If it is, the procedure is over. Otherwise decision maker analyzes the available information and feeds new one to the computer for a new decision to be prepared. At optimization phase the computer employs information provided by the decision maker in order to develop a new decision, and produces new information to the decision maker.

To-day, there are many man-machine procedures of multicriteria linear programming [14] . They differ in contents and performance of analysis and optimization phases. Given a wide variety of procedures, they are divided into three types depending on the role of man in the organization of search for a desired decision [14] .

With non-structured procedures decision maker carries out a direct search for the best decision X^*. With structured procedures he exercises some rather simple operations at the analysis phase not defining a preferable decision at the given step but just directing the computer to an approximation to this decision. In-between are pseudo-structured procedures wherein decision maker does not look for the decision X* at each phase but performs auxiliary operations. However, by their content the latter are as difficult for the decision maker as the search for X^*.

Psychological problems of decision-maker-computer interaction have to be seriously dealt with in developing man-machine procedures of multicriteria mathematical programming. At the analysis and decision making phases the information processing operations take place. The recent psychological studies indicate that the operations with non-structured and pseudo-structured procedures are too complex for decision makers [14] . No clear estimates of the number of operations in some structured procedures are available. Additional psychological research is needed to substantiate the correctness of many procedures.

PSYCHOLOGICAL PROBLEMS OF DEVELOPING THE SYSTEMS ASSISTING IN UNIQUE DECISION MAKING WITH SUBJECTIVE MODELS

The man-machine systems designed for solution of unique problems of choice serve two purposes: structurization of the problem and elicitation of decision maker's preferences. It must be noted straight away that the two problems substantially differ in complexity.

The elicitation problem is usually solved within the framework of some approach to the formulation of decision rule. It is assumed that the problem structure has been defined. In the course of decision maker-computer interaction the former carries out necessary measurements of individual components of the utility function. Thus, for example, with axiomatic approach [11] use is made of man-machine procedures for the formulation of utility functions by individual criteria with a view to checking up independence conditions, defining the type (additive or multiplicative) of the general utility function.

In this case, computer helps the analyst (or decision maker familiar with decision methods) to quickly exercise all auxiliary computations and make the process of decision rule formulation more convenient for the decision maker.

Quite different is the problem of structurization. In the course of its solution decision maker tries to formalize his idea about the decision problem, for example, what variables should be employed as criteria of decision alternative estimates. As for structurization, it does not require any computations but only a logical analysis which has been traditionally carried out by the tandem of an experienced analyst and decision maker.

A question arises as to what degree the computer is helpful in problem structurization.

In case a direct utilization of computer by a person conducting a

search for an adequate structure of his problem, the computer will hardly be able to replace the analyst. There are data that people prefer a dialogue with an analyst rather than with a computer.
A systematic comparison of the two methods of work with decision makers was conducted by W. Edvards et al [9] whose conclusions were not in favor of computer. Though some people perceive computer as an "especially intelligent interlocutor" [26] it is clear that in the problems of preliminary analysis the analyst's skills, his creative search, the ability to find a new formulation of the problems cannot be taken over by computer. There are few exceptions, though, when the structure is defined in general but it is necessary to specify the parameters (e.g. a set of criteria). In such cases the computer has an abundant information, "requisite model" [16] used as a framework for the final choice.
An alternative to the direct decision maker-computer interaction is computer use by the analyst who, together with decision maker carries out search for a respective structure of the problem. The computer utility in this case in largely determined by the sophistication of software which must provide for the possible types of preference structures. Under the assumption of the possible type of structure (e.g. a set of independent criteria) the use of DSS can happen to be succcessful. Thus, the successful application of the system of MAUD [8] both for structurization and for preference identification indicates that for some users the system was quite suitable.
In using the computer as a tool assisting the consultant to develop decision rules on the basis of decision maker preferences, the complex problem is to define correct methods [12] for identifying decision maker preferences, It is desirable to employ such ways for eliciting information from decision maker that are commensurate with his abilities [15] .
The psychological validation of the methods of eliciting information from people is of high significance. It is quite possible, for example, to develop an interactive program allowing decision maker to plot the probability distribution curves. However, the knowledge of the systematic errors people make while assessing event probabilities [10] does not allow to consider this method of information elicitation as reliable.
In case a hypothesis on the reliability of a certain method of eliciting information from people is tested, and if there are

(diagnostics) rather than problems of synthesis. Complete though the set of attributes (criteria) may be, an experienced physician takes into consideration, in real life situations, a lot of other things when studying a specific patient.
Extremely complex for the physician is the problem of developing decision rules. In a decision language this problem may be treated as a problem of direct classification (reference to the classes of diseases) under a huge number of criteria. The research we have conducted [15] allowed us to find approximate "limits of capacities" of decision makers in such problems. It must be noted that in the development of many of the expert systems the decision maker tasks are beyond the limits. Hence, highly simplified strategies can be expected to evolve in many cases. In connection with the aforesaid it becomes clear that the quality of expert systems is inferior and must be inferior to the skill of an experienced physician (though sometimes be superior to the unexperienced physician, a beginner).

ELEMENTARY OPERATIONS AND THEIR PSYCHOLOGICAL VALIDITY

Given a wide variety of decision support systems we may single out a comparatively small number of elementary operations in information processing performed by a human being. There are four classes of elementary operations:
1. Operations with criteria (assignment of weights, ordering by importance, etc.).
2. Operations with criterion scales (comparison of estimates on scales, measurement of estimate utility, etc.).
3. Operations with alternatives (comparison, measurement of probabilities, reference to a quality class, etc.).
4. Operations with alternative estimates by criteria (comparison, definition of a satisfactory value, etc.).

Each of the above four classes of operations is referred to as elementary if it cannot be expanded into a set of other operations relating to objects of the same class. Every man-machine procedure can be represented as a set of elementary operations. Thus, for example, one of the procedures of choice with an objective model - Geoffrion-Dyer procedure of solving multiattribute mathematical programming task [7] can be characterized by the following elemental steps of eliciting information from decision maker:
1. Determination of the numerical value of estimate increment on

ways of checking the information while obtaining it from decision maker (see, for example, the method of ZAPROS [13]) then this method may be reliably used in interactive systems for eliciting information from decision maker. Otherwise, questions complex for a decision maker can result in simplifications, application of heuristics, and in contradictions.

PSYCHOLOGICAL PROBLEMS OF DEVELOPING EXPERT SYSTEMS IN HOLISTIC CHOICE PROBLEMS

In holistic choice problems the decision maker has a general estimate of some or other decision suitable for him. Accordingly he is able to effectively influence the choice. At the same time human behavior in holistic choice problems is often far from rational. In studying different alternatives of one and the same decisions a person may take into account different (and not the same) properties thereof, he can miss some properties of the system important for evaluation (as if they are overwhelmed by "gestalt"). Besides, different decision makers differ in skills as expert, and the estimates of inexperienced experts can distort the entire situation of choice.

In this connection during the last 1o - 15 years there have been attempts to develop the so-called expert systems [4] making use of decision rules of the most experienced decision makers. These have been traditionally referred to the area of artificial intelligence.

As is well known, expert systems consist of three major parts [4]: knowledge base, data base and control program. The quality of the system considerably depends on the knowledge base. The latter is often developed in an interactive mode with the expert whereby a set of attributes is identified that rather fully characterise the holistic images and a rule of transition from a set of attributes to the images. Both the first and the second problems are rather complex for decision maker.

As is known the majority of the existing expert systems belong to the area of medical diagnostics. By assigning a set of attributes, characteristic of a certain group of diseases, the physician always stems from an abstract idea about the patient, develops some generalized image. This task is unusual, hence difficult for the physician. It has been noted [5] that in the day-to-day practice physicians generally solve problems of analysis

a single criterion scale equivalent, by utility, to the increment by another criterion scale.
2. Comparison of utilities of two multiattribute alternatives.
Another technique, designed for solution of problems of the same class, i.e. STEM method [1] comprises the following operations:
1. Selection of the criterion whose estimates must be improved in the first place.
2. Assignment of a satisfactory value of this criterion.
3. Comparison of the two criteria estimate variations.
The ZAPROS method [13] for solution of unique choice problems with subjective models comprises two elementary operations:
1. Comparison of alternatives differing in estimates by two criteria, wherein the rest of the estimates refer to the reference situation (best or worst).
2. Comparison of utility variation between the estimates by a single criterion scale.
In developing expert systems use is made of the following elementary operation: reference of an alternative (represented in the form of a set of estimates by multiple criteria) to one of decision classes.
In a similar way it is possible to analyze any procedure of decisionmaker - computer interaction.
Each elementary operation of eliciting information from a person can be analyzed with regard to the following issues:
1. Is the given elementary operation a sufficiently reliable tool for eliciting information from a person (i.e. is it within the "limits of human capacities") [15] ?
2. Do the human capacities, in performing the elementary operations, depend on the problem variables (number of criteria, alternatives, etc.), and what is this dependence?
At present the insufficient results of psychological research do not allow to answer these questions with respect to all elementary operations. There is, however, a considerable knowledge about some of them.
Let us consider two elementary operations: 1) comparison of two multiattribute alternatives; 2) reference of a multiattribute alternative to one of several quality classes.
A) <u>Comparison of two multiattribute alternatives</u> (i.e. alternatives represented as a set of estimates by criteria).
There is a systematic research conducted by I.Russo and his associates [18,19] indicating that even given three-four criteria

people make considerable errors in performing this operation, employ simplified heuristics.
For alternatives, differing in estimates by two criteria (and other estimates are the best or the worst) there are indications of reliable decisionmaker's performance with up to seven criteria [13] .
B) <u>Reference of a multiattribute alternative to one of quality</u> classes (e.g. to a class of good or bad ones).
There are results of systematic research [15] indicating that given the discrete scales of criterion estimates the decision maker performs this operation quite reliably within the limits characterized by the following table (the blocks of Table 2 contain the number of criteria):

Table 2

	Number of decision classes				
		2	3	4	4
Number of estimates on ordinal scales	2	7-8	6-7	5	2-3
	3	5	2-3	2-3	2
	3	2-3			

So, it is obvious that should the limits be exceeded, people either employ simplified heuristics or produce a large number of contradictory answers.

CONCLUSION

Thus far the development of decision support systems was distinguished by employment of more and more convenient, flexible and sophisticated computational tools. Far more modest are successes in the assistance rendered to people in solution of complex problems of choice.
Any substantial advance in development of effective DSS will depend on adaptation of computer capacities to specifics of the human information processing system. Only the consideration of these specifics will allow to create in future some genuine amplifiers of decision maker's intelligence.

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