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Computer support of group decision making

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Abstract

In this paper we consider techniques of computer group decision making support. The interrelation of support methods, negotiation process type, and character of problems to be managed is shown. The structure of a computer-aided system supporting group decision making is offered, and some methods to support the course of negotiations using such systems are discussed.

1 Introduction

Group decision making is usually understood as achieving of an agreement common for all group members about evaluation of considered processes or objects based on individual opinion of each group member. I.e., the transition is made from the given individual opinions to a uniform collective opinion which the negotiators agree with, and on whose basis the group decision is obtained.

The basic condition for success of negotiations which are not held from the position of force is satisfaction of interests of the contracting parties on the basis of the compromise, i.e., achievement of conditions, at which each of the contracting parties gets a certain gain.

The essential part of the group decision making process consists in negotiations, often being very time-consuming and complicated. As the group decisions constitute a powerful share of all decisions made by politicians, businessmen, managers, engineers and other specialists, a significant part of their life is spent in the course of negotiations which are very various in their subjects and significance. During the negotiations they should take into account a plenty of factors, interests and complex oppositional forces rendering influence on a course of negotiations and the decision made as its result.

The course of negotiations is complicated by problems of weak structuredness of considered problems and of uncertainty connected with the fact that managers or experts can not precisely foresee and evaluate the consequences of decisions they make. Poorly structured problems have a lot of unpleasant features. They do not always allow to formulate them precisely and search their solution. They can contain no objective measure of successful results, in which case it may be substituted with expert estimations. They require as a rule an iterative process of decision making. Often there are no ready alternatives of the decision, thus each alternative should be found in the course of decision making, etc. [1].

The uncertainty is an integral accessory of decision making processes. It is connected with incompleteness of our knowledge about a problem under consideration and with inaccuracy of understanding of his goals by a manager. It is possible to distinguish external, internal [2] and personal [3] uncertainties.

The external uncertainty is connected with the factors with a very weak degree of dependence on the will of the manager or being outside of his control. This is the behavior of the partners in negotiations, in some cases actions of imperious structures, or character of demand, etc. The subjective evaluation of these factors renders the strongest influence on the results of negotiations.

The internal uncertainty is connected with the factors, on which the manager can render the influence which is strong enough. This includes the effectiveness of management in the organization, amount and quality of resources, qualification of experts etc. These components can render decisive influence on negotiations about junction of companies, creation of the joint projects, etc.

The personal uncertainty is connected with oscillations in a choice of means used to achieve the goal, with doubts in a choice and in evaluation of criteria, in choice of mathematical models, etc.

Naturally, during the process of coordination of individual decisions the uncertainties in estimations of each expert or manager participating in negotiations are imposed against each other making additional complexities. The more is degree of uncertainty, the greater weight in decision making and their coordination have subjective estimations of a manager. Manager's subjective estimation is an estimation made on the basis of his own experience, intuition, preference or interest, instead of on the basis of absolutely exact knowledge. The subjective estimation will eliminate the uncertainty. There is nothing bad in such a subjectivity. The experienced managers and engineers know well, how many personal and subjective details are introduced by them into decisions they make. Therefore subjective estimations should be regarded during the formal analysis as input data. Naturally, the obtained results also should be regarded as subjective.

Abovementioned complexities and some other ones, impossibility or inefficiency to make simple decisions based on the power, duration and intensity of negotiations result in the natural desire to use computer-aided systems supporting experts and managers who participate in group decision making activity. Such systems are named negotiation support systems (NSS).

2 Purpose and structure of a computer-aided negotiation support system

The computer-aided negotiation support system is intended to render assistance to the negotiators in their activity and in obtaining common concerted decision. The help provided by the NSS consists in:

- organization of communication between all negotiators by means of the computer network irrespective of where they are, and providing them the possibility of easy exchange of the offers and counteroffers;
- the possibility of operative visual presentation onscreen all the information necessary during negotiations using multimedia techniques;
- help in evaluation of priorities for separate components of a discussed problem during all course of negotiations;
- providing the means for formalization of offers made by each negotiator, and for their evaluation, including algorithms, ranking techniques and simulation of decision consequences;

- simplification of development by all participants and groups of negotiators of a common approach from various points of view to the discussed problem by the means of their formalization and analysis, taking into account interests of each partner;

- generation of compromise variants of the common decisions and of their estimations;

- simulation of consequences of offered decision variants.

Special efficiency of NSS implementation consists of the comprehensive approach to the negotiation support, beginning with training in conduction of negotiations with the help of the system and finishing with making an agreement on a real problem. An example of such approach is the NSS INSPIRE [4], which provides four variants of its usage.

1. Possibility to held educational games in the field of group decision making. INSPIRE provides for the unexperienced participants a step-to step manual on the process of negotiations. For more experienced experts, the system gives to the player the possibility to construct a graphical track of the course of group decision making process by means of numerous rounds of exchange of offers and counteroffers.

2. The decision support system can be used as a tool of preparation to negotiations. Before the beginning of negotiation process each participant is obliged to evaluate possible results and their variants. It causes him to formulate precisely his preferences and to consider possible paths to find the compromises. The system allows to make evaluations of various combinations of variants and to produce the general evaluation of all decision packages.

3. Application of simulation means to the forthcoming negotiations permits to prepare yourself to the real discussion on problems. Real conditions of negotiations are entered into the system, and the game is carried out imitating possible variants of a course of real group decision making process. These means can be used also in parallel with real negotiations, like chess players use chess

programs during the course of their matches (if it is permitted by the rules).

4. Support of real negotiations with the help of a negotiation support system, to which category, in fact, the INSPIRE system belongs. As a result of training sessions and situation analysis held before negotiations, the negotiator can use all possibilities of the system for successful conduction of negotiations. It is important to note, that in all cases the system can operate through the INTERNET.

Starting from described in the literature and often found there sequence of negotiation stages (without computer support), the structure of a negotiation support system can be shown in Fig. 1. The arrows show the sequence of stages and possible loop-wise character of process.

From Fig. 1 one can see that the computer-aided negotiation support system having such a structure provides support at all negotiation stages, starting from gathering of information and finishing with creation of documents on decision that was made. It is possible to consider NSS as a functionally distributed system, if it is is installed only on one computer of one of the participants or as a functionally and space distributed one, if it is used by several participants situated at distances from each other.

Of course, Fig. 1 is only a scheme illustrating the functionality of a negotiation support system. As the negotiations are conducted on various occasions, in various conditions, with various interrelations between negotiators, the structure of negotiations represented in Fig. 1 is not universal, but it shows the general scheme of preparation to negotiations and to conduction of them with the help of NSS. In each particular case some separate elements of this scheme can be not used, and some new may appear. The structures of program complexes for real NSS can differ from the scheme of Fig. 1, though it is convenient to consider the operation of negotiation support systems basing on this structure.

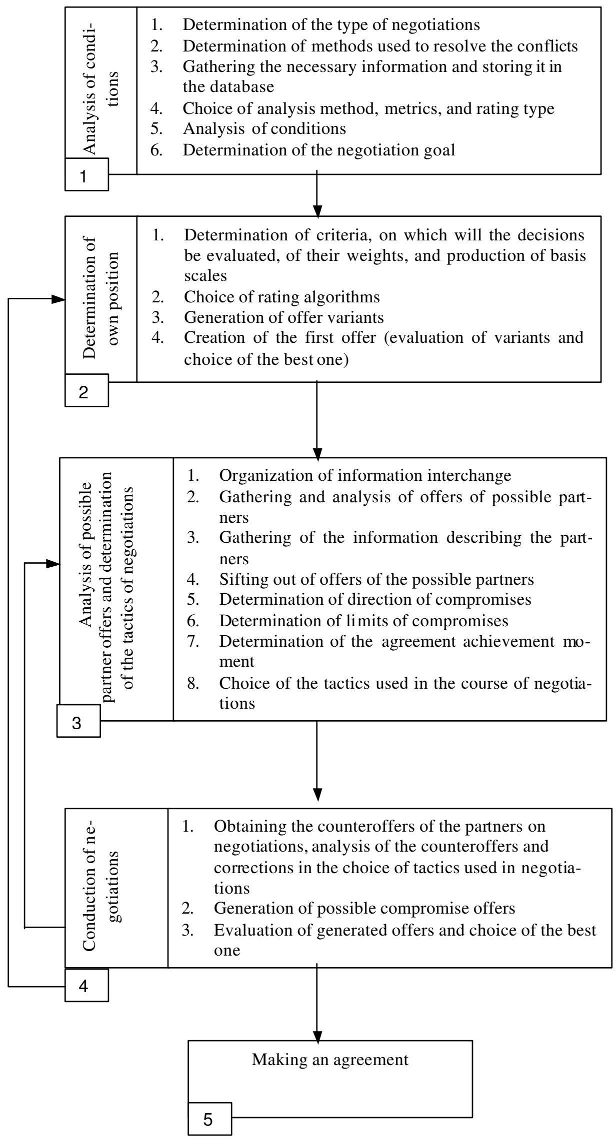
Analysis of conditions
1. Determination of the type of negotiations
2. Determination of methods used to resolve the conflicts
3. Gathering the necessary information and storing it in the database
4. Choice of analysis method, metrics, and rating type
5. Analysis of conditions
6. Determination of the negotiation goal
1
Determination of own position
1. Determination of criteria, on which will the decisions be evaluated, of their weights, and production of basis scales
2. Choice of rating algorithms
3. Generation of offer variants
4. Creation of the first offer (evaluation of variants and choice of the best one)
2
Analysis of possible partner offers and determination of the tactics of negotiations
1. Organization of information interchange
2. Gathering and analysis of offers of possible partners
3. Gathering of the information describing the partners
4. Sifting out of offers of the possible partners
5. Determination of direction of compromises
6. Determination of limits of compromises
7. Determination of the agreement achievement moment
8. Choice of the tactics used in the course of negotiations
3
Conduction of negotiations
1. Obtaining the counteroffers of the partners on negotiations, analysis of the counteroffers and corrections in the choice of tactics used in negotiations
2. Generation of possible compromise offers
3. Evaluation of generated offers and choice of the best one
4
Making an agreement
5

Figure 1

3 Analysis of conditions

The computer support of the analysis of conditions consists in usage of methods revealing the latent legitimacies, and the determinative factors rendering influence on the possible development of situations, and on the character of threats and/or of favorable factors arising, on the basis of the information stored in the database and of experts' or managers' ratings.

3.1 Determination of the type of negotiations

Situations arising during negotiations can be divided by their types into the following classes.

- Distributive ones (they are also named competitive, games with zero sum, etc.). In negotiations of this class one party "wins", and other party "loses". It occurs when there exists a fixed resource, the distribution of which constitutes the very subject of the negotiations.
- Integrational ones (they are also named amicable, of "success–success" type, etc.). Both parties can "win" in negotiations of this class because the amount of the resource is variable, not fixed. A majorant of such negotiations is the maximization of a total common advantage. It is achieved by exchange of information and by joint solution of problems. It can take place, for example, in the case of junction of two companies.
- Integrational-distributive ones, which contain features of both classes mentioned above. An example of negotiations of this class is presented by relations of constant suppliers and buyers of their goods. Each of them wants to obtain a maximum of profit at the expense of other, though each party wants also that the other one will be satisfied.

3.2 Type of methods used to resolve the conflicts

The methods used to resolve the conflicts can be classified in the terms of the attitude to satisfaction of own and opponent's demands:

- the egoistical one; the satisfaction of own demands is important, of partner's ones is not important;
- compromise; the satisfaction of both own and partner's demands is important;
- indifferent, satisfaction of both own and partner's demands has no value;
- compliant; the demands of the partner on negotiations matter only, they are only satisfied. The vivid example of negotiations of this type is an unconditional surrender.

Let's designate the usefulness function of negotiation results for one of the parties by $\pi(z)$, and for other by $\Psi(z)$. Each party knows its own function, but, as a rule, does not know other one's function. Let z be vectors of arguments of these two functions. The area of definition of arguments can be common for both functions or be own for each function, but they should necessarily intersect. Since we are interested only in intersection area, just it is designated by vector z.

We shall designate extremal points of functions $\pi(z_0^x)$ and $\Psi(z_0^y)$. In general case points z_0^x and z_0^y do not coincide. Each of the parties wants come to its extremal point at termination of negotiations, though the termination moment largely depends on tactics used during the course of negotiations. Therefore it is possible to consider functions describing a course of negotiations, as composition of two functions. For the party X it is the composition of a function $\pi(z)$ and $\alpha(z)$, and for the party Y the composition of functions $\Psi(z)$ and $\beta(z)$, where $\alpha(z)$ and $\beta(z)$ are functions describing tactics of negotiations of the parties X and Y accordingly. These compositions we shall designate by functions $f_x(\pi(z), \alpha(z))$ and $f_y(\Psi(z), \beta(z))$.

Designating the point where the agreement is achieved through z_c, both parties will accordingly try to achieve the following:

$$|pi(z_0^x) - f^x(\pi(z_c^x)\alpha(z_c^x))| \to \min$$
$$|\Psi(z_0^y) - f_y(\Psi(z_c^y), \beta(z_c^y))| \to \min$$

In the case of egoistical tactics of partner X $f^x(\pi(z_c^x), \alpha(z_c^x)) = \pi(z_0^x)$, irrespective of tactics of partner Y.

In the case of compromise tactics of both partners X and Y,

$$A|\pi\ (z_0^x) - f^x(\pi(z_c^x), \alpha(z_c^x))| = B|\pi(z_0^x) - f^y(\pi(z_c^y), \beta(z_c^y))|,$$

where A and B are vectors, at which the compromise is achieved, since generally

$$|\pi(z_0^x) - f^x(\pi(z_c^x), \alpha(z_c^x))| \neg |\pi(z_0^y) - f^y(\pi(z_c^y), \beta(z_c^y))|$$

In the case of indifferent tactics of partners X and Y neither the type of functions $\alpha(z)$, $\beta(z$, nor the value of functions $\pi(z_c^x)$ and $\Psi(z_c^y)$ are important.

In the case of compliant tactics of partner X $f^x(\pi(z_c^x), \alpha(z_c^x)) = \Psi(z_0^y)$ irrespective of tactics of partner Y.

Other items of the block 1 in Fig. 1 are traditional for analysis blocks of decision support systems. Now computer-aided analysis systems are used very widely. Since methods used hardly depend on the area of analysis they will not be considered in this article.

4 Determination of own position

In the literature on methods of negotiations (not connected with usage of computer facilities), the importance of determination of own position before the negotiations start (some kind of the home task) for success in forthcoming negotiations is underlined. We shall see now that this stage is also extremely important at negotiations with usage of decision support systems.

4.1 Determination of criteria to evaluate achieved agreements, their weights, and basic scales

Choice of criteria on which the agreements achieved during negotiations will be evaluated depends, of course, first of all on manager, and can be very individual; on the other hand, there exists some traditional set of criteria, in which some additions or changes can be made by a manager or an expert. The role of NSS may be reduced here to presentation to the manager of the list of more or less standard criteria, which will be changed by the manager according to his own preferences and interests. In this case he should not be confused when his preferences differ from generally accepted ones.

Determination of rating criteria is an important moment. The first desire of any manager is to indicate maximal possible set of criteria, attempting to connect each parameter with an independent criterion. Increase of number of criteria, as though, should increase accuracy of problem solution, since the greater number of factors is taken into account. On the other hand, if these factors are taken into account incorrectly, the error value increases.

The rating of criterion importance (its weight) can be expressed:

- directly by numbers, e.g., as it is shown in Tab. 1;
- matching with some base criterion (for example, with cost);
- by pairwise matching of criterion importances.

Table 1

Criterion	5 points Very well	4 points Well	3 points Average	2 points Satisfactory	1 points Bad
Quality	The highest quality	Exceeds minimal standard demands	Corresponds to minimal standard demands	In some cases does not correspond to minimal standard demands	In rare cases corresponds to minimal standard demands
Price	Below than average price more than by 5%	Below than average price no more than by 5%	Corresponds to average price	Above than average price no more than by 5%	Above than average price more than by 5%
Delivery time	Less than average delivery time than by 10%	Less than average delivery time no more than by 10%	Corresponds to average delivery time	Exceeds average delivery time no more than by 10%	Exceeds average delivery time more than by 10%

In all three cases they can be expressed numerically (in points), graphically on the display (for example, by the height of a bar which shows the weight or comparative weight of criterion) or in the form of a linguistic variable.

Determination of criterion weight is far from being always a simple problem, since managers, understanding from their experience relative importances (weights) of each criterion, have not got used to express this importance by numbers or linguistic ratings. At the same time incorrect evaluation of criterion weight will result later in incorrect evaluation of intermediate and of final variant of the agreement.

Determination of criterion weight using the two first methods can result in errors in determination of these values, but can not cause logical inconsistencies. The method of pairwise matchings in many cases can appear be more convenient for the manager, but it can result in logical inconsistencies.

One of the ways of reduction of a multicriteria problem to a precisely determined goal is elimination of uncertainty by mapping physical parameters into criteria estimations (either linguistic ones or point values). For this purpose scales often called basic ones are used. In section 2.4 the examples of such scales are shown. Combining these scales, it is possible to obtain many-dimensional base space. NSS presents to a manager or expert intervals of physical parameters, accepted in practice, he corrects them, if will find it necessary, and then sets linguistic or point ratings for each interval. So he also determines his subjective estimation of physical parameters.

The questions of choice of criteria ratings and construction of basic scales are considered in works [1, 2, 3, 5, 6].

4.2 Choice of rating algorithms

During determination of a set of criteria, their weights and basic scales the manager or expert can express in understandable for him terms his subjective estimates of successfulness (or failure) of a possible joint decision. When choosing the rating algorithm there is no such a priori clarity. Using different algorithms one will obtain different ratings of variants of common decision. Of course, in some cases they can coincide, but this is an exception, not the rule. This exception arises usually when one of objects of the ranked set exceeds others by all or by most significant parameters.

Let's begin with consideration of a rating method for variants of decisions frequently used in cases of estimation of financial profitability of projects named net present value [7]:

$$V = \sum_{t=1}^{T} \frac{B^t - C^t}{(1+E)^t)},$$

where B^t is an income for one year t, C^t are costs for one year t, E is a rate (norm of discount).

Considering that costs are determined only by capital investments and by operation costs, depending on a situation the revenue value can vary. In this case forecast of incomes is a subjective estimation of parameter significance made by a manager, which depends also on his strategy of behavior. Then the function V can be written down in the following way:

$$V_y = \sum_{t=1}^{T} \frac{B_y^t - C_y^t}{(1+E)^t}, \tag{1}$$

where i is one of events which can reduce (or increase) yield and/or increase (reduce) the costs, and j is one of the strategies of behavior, which the manager is going to use.

On the basis of usage of functions like V_{ij} the rather large number of criteria of efficiency is offered.

One of them is the maximum value of a minimum gain. Formally this pessimistic criterion proceeds from a principle "it may not be worse". It looks like this:

$$W = \max_i \min_j V_{ij} \tag{2}$$

This criterion is referred in the literature as Wald's criterion. It expresses the position of extreme pessimism.

The criterion of minimal risk is close to the previous one, though it is oriented not to gain, but to risk.

$$S = \max_i \min_j \alpha_{ij}, \tag{3}$$

where α_{ij} is the value of risk for variant i, j. This criterion is referred in the literature as Savage's criterion.

It is necessary to mention that the problem of risk determination is difficult enough by itself, and we shall not consider it. Using this criterion at decision making one tries to avoid the great value of risk.

At last, there exists some intermediate variant between the extremely pessimistic and extremely optimistic ones, namely Hurwitz's criterion.

$$H = \max_i [\beta \min_j V_{ij} + (1-\beta) \max_j V_{ij}], \tag{4}$$

where $0 \leq \beta \leq 1$ is the "factor of pessimism" or, if one wants, the "factor of optimism". When $\beta = 1$ Hurwitz's criterion turns into Wald's criterion, and when $\beta = 0$ it turns out to be a maximum optimistical one.

It is necessary to underline, that determination of β value is a prerogative of manager, and from this point of view Hurwitz's criterion is extremely subjective.

Of course, functions (1)–(4) are only a few examples from the very large number of functions, algorithms and methods of ratings for capital investment efficiency. One of such methods is the method of mathematical models.

The questions of application of mathematical models to the analysis of problems of decision making in economy, ecology, politics and a number of other areas, the laws of operation in which are still badly formalized and investigated, can not be considered in the same manner like, for example, in physics, in which mathematical models result from successful enough centuries-old researches. In economy, ecology, politics and some other areas mathematical models are too rough, sometimes give even incorrect qualitative predictions. It is connected, in particular, both with huge complexity of these problems, and with their dependence on the purely subjective factors, besides it is necessary to take into account that the object of simulation can appear to be unstable. Therefore the attitude to results of simulation of problems relating these areas as something absolute, so natural, for example, in the majority of areas of physics, is invalid.

The solution of this problem can be found using mathematical models and methods for estimation of possible scripts (variants of decisions), which are regarded as a recommendation for subsequent estimation by a manager and, probably, for informal analysis. For the description of such models the various mathematical apparatus is used: methods of subjective probability, fuzzy sets, neuron networks, piecewise linear approximation, Markov stochastic processes, methods of mathematical programming, etc.

4.3 Generation of offer variants

The computer generation of possible offers can be carried out by means of program implementation of analytical or simulation models, usage of consulting models, generation of the scripts by a combination of various operations given by the manager or taken from the database, and, at last, usage of the approach which is named situational management.

Prognostic methods are used as a rule to generate decisions. Two types of the forecasts are distinguished: retrieval and normative ones [8]. The retrieval forecast is the determination of possible states of the system in the future. The normative forecast is the determination of ways and terms of achievement of possible states of the system which are set as a goal. One can divide the process of generation of normative decisions using methods of a combination of various operations selected on the basis of subjective preferences of the manager, into three sequential stages: creation of a cognitive map, creation of the knowledge base of consulting model and generation of a set of scripts [9]. The subsystem of decision generation in a decision support system can correspond to each stage.

Here it is necessary to underline that not all three subsystems may be included into a NSS, moreover, each of these subsystems can function independently.

The retrieval forecast answers the question: what is the most probable situation, that will take place under condition of preservation of existing tendencies. For implementation of the retrieval forecast various statistical methods are often used. As an example, we shall consider the scheme of forecast using the general trend model in the case of consistency of expert ratings [10].

Let the forecast of the process be represented in the form of a sequence of observation results:

$$\widetilde{y}_t, \quad t = \overline{1, m}, \tag{5}$$

and the set of consistent (noncontradictory) expert ratings:

$$\{w^l, \quad l = \overline{1, L}\} \tag{6}$$

can be represented by the conjunction: $\cup_{l \in L} w^l$.

In general w^l can be a complex statement consisting of some set of elementary statements. In some particular case w^l can be a single statement of a type:

$$\alpha^l + \beta^l y_\mu^l \geq \gamma^l + \delta^l y_V^l, \quad l = \overline{1, L}, \tag{7}$$

where μ and ν are moments of period of anticipations, and α, β, γ, δ are ratings provided by the experts. This simple case is considered below.

In the case of forecast, a key question is always the choice of the model class. This choice depends on subjective preferences of the expert and can render serious influence on the result of forecasting.

Let the class of models with linear dependencies on parameters be selected:

$$F(t, \theta) = (\theta, \phi(t)) \tag{8}$$

determined in discrete time points $t = \overline{1, m}$, where θ is a vector of parameters, $\theta = (\theta_1, \ldots, \theta_k, \phi$ is a vector function $\varphi = (\varphi_1, \ldots, \varphi_k)$, the components of which are the known vector functions of time, and $psi, \varphi(t)) = \sum_{i=1}^{K} \psi_i \varphi_i(t)$ is a scalar product. The dependence (8) is named the trend function (or trend model).

The problem consists in the search of a prognostic sequence best corresponding to observation results (5) and expert ratings (6).

Whereas the duration of observation period is unsufficient to obtain reliable statistical conclusions, estimation the parameters of the model is often started from model's correspondence to expert ratings, and only after that is required correspondence to observation results. I.e., this method of forecast is actually based on subjective preferences of experts.

The correspondence of model (8) with expert ratings (6) means that:

$$y_i = (\psi, \phi(t)), \quad t = \overline{m+1, m+n} \tag{9}$$

and, therefore, linear inequalities (7) should hold.

The correspondence of model (8) with observation results (5) is determined by the fact, how the values, calculated using the model, of a temporal series are close to observable ones. As a measure of closeness the following sum may be taken:

$$D(\theta) = \sum_{t=1}^{m} R(\widetilde{y}_t - (\theta, \phi(t))), \tag{10}$$

where R is a some is strictly convex function (for example, square or absolute value of a real number).

As a result we come to a minimization problem:

$$\min_{\theta_t} D(\theta) \tag{11}$$

with limitations (7).

Solving the problem (10), (11), (7) we find a vector of parameter ratings of trend model $\theta = (\theta_1, \ldots, \theta_k)$, and then in correspondence with (9) we create a prognostic sequence:

$$y_t = (\theta, \phi(t)), \quad t = \overline{m+1, m+n}.$$

Since the system of inequalities (7) in the case of noncontradictory expert ratings is compatible, the problem of minimization has a solution, and this solution is unique by virtue of strict convexity of function R and, therefore, of function D.

Let us note that the solution of a problem with the given expert ratings is really unique, but in most cases expert ratings hardly depend on the personal complement of the experts board, on their experience in a domain of the problem under consideration, etc.

4.4 Creation of the first offer (evaluation of variants and choice of the best one)

For creation of the first offer, that is, its choice from the set of generated by NSS ones, it is necessary to evaluate them, rank them, and then select the best one.

In many cases creation of the first offer is implemented by means of solution of optimization problems. Several typical examples are described below.

For so-called industrial problems often the canonical problem of linear programming is characteristic:

$$CX \to \max,\ AX = B,\ x_y \geq 0,$$

where C is a vector of factors, A is a matrix of parameters, X is a vector of variables, B is a constraint vector.

To solve the transport problems the method of optimal flow (minimal cost flow) can be used which gives the solution of a problem:

$$\sum_{(i,j)\in U} c_{ij}x_{ij} \to min,\ \sum_{i\in I_t^+} x_{ij} - \sum_{j\in I_t^-} x_{ij} = a_i,\ i \in I,\ x_{ij} > 0,\ (i,j) \in U,$$

where $(i,j) \in U$ is the set of arcs, c^s_{ij} is the cost of single arc of the flow, I_t^+, I_t^- is the set of nodes which are connected to node i by arcs from U, starting in i (or terminating in i), $\sum_{i,j\in U} c_{ij}x_{ij}$ is the cost of the flow.

For solution of a widely known problem of a choice from a collection of n objects some number of them having the minimal weight (or volume, or value of harmful ejections, etc.) with the given value (or productivity, toxicity, force of explosion etc.) the problem of the boolean programming which is named the knapsack problem can be applied.

$$f(x)m = \sum_{i=1}^{n} P_i x_i \to \min,\ \sum_{i=1}^{n} c_i x_i,\ x_i = 1,0,\ i = \overline{1,n},$$

where c_i is the value of i object, P_i is the weight of i object, c is the given value for selected objects.

It is necessary to underline, what even after all the variants are estimated, it is not a simple problem to rank them consistently and to define the best among them. Some examples of choice paradoxes are considered in [11].

5 Analysis of offers of possible partners and determination of the tactics of negotiations

For the preliminary analysis of offers of possible partners and determination of the tactics of negotiations NSS should execute functions shown in the block 3 at Fig. 1.

5.1 Organization of information interchange

It is possible to distinguish two kinds of dialogue at multilateral negotiations:

- Conferences of the type "single time – single space", when all negotiators are situated in a single common premise,
- Conferences of the type "single time – different space", when the participants are territorially separated.

In both cases the distributed negotiation support system can be used for organization of information interchange.

Distributed computing systems can be distributed in space and/or in functions. Spacewise or functionally distributed NSS consist of local NSS, disposed in the sites of a computer network, connected to each other. Each of them can independently solve its particular problems, but for solution of a common problem any of them has no sufficient information and/or resources. They can solve the common problem only together, consolidating the local possibilities and coordinating separately accepted decisions. Spacewise distributed systems consist of a number of NSS, installed on various computers. Functionally distributed systems consist of a number of NSS, connected to each other and installed on a single computer.

The structure of the transmitted information should be determined for information interchange between the participants of discussion. It can be various in various systems. E.g., in the INSS system [12], three structures of the transmitted information are possible.

- Parallel. In this case each negotiator has the right to present only the complete package of offers. This protocol can appear to be more difficult in use than a sequential one, since negotiators should simultaneously take into account all problems, factors and possible results, instead of considering them separately. This mode is not allowed in some systems. E.g., in the INSPIRE system [4] it is prohibited.

- Sequential. In this case each negotiator can make one or several offers in each message and answer. The complete package of offers or answers is not required. This protocol frequently is used in household situations, but not because it is more effective than parallel, but by virtue of lower requests to qualification of negotiators.

- Unstructured. Some NSS allow only exchange of offers. In these systems users can send to their partners packages of offers, but can not append their arguments, explications or reasons.

Graphical NSS systems are gaining popularity now for their organization of information interchange. An example of such systems is the QuestMap system [13]. It is a graphical system, convenient in usage, which provides group data processing and information interchange during the process of common decision making.

QuestMap represents processes, objects, and their sequences not textually, but by a graph whose vertices are icons with brief desctiption. Signs "+" and "−" referred to them designate positive or negative influence. The graph map size is not limited. Each vertex of the graph can in its turn generate the subgraph.

QuestMap provides a teleconference, allowing to receive all available texts, tables, and other information from each icon. The date of its appearance on the graph is also shown. Each member of QuestMap conference can send messages to any other member of conference, or organize the subgroup on any special question inside the conference.

5.2 Collection and analysis of the offers of possible partners

The collection of the offers is implemented by means of information interchange. The rating of the possible partners can be implemented by various methods. For the analysis of the counteroffers of the partners, they are compared by criteria formulated at determination of the item, their deviation from the given conditions and, probably, from a determined ideal point, and also by other criteria. Unacceptable offers are sifted of the offers that fulfil conditions of the negotiation initiator.

Each of the possible partners is evaluated by the experts against criteria defined by the manager. The ratings are entered in a negotiation support system. If possible partners satisfy to the given limitations (for example, by all criteria the rating should be not lower than "well", and on quality is "excellent"), they are enlisted by the system in the list of partners.

The rating of the partner's offers is made by various functions or algorithms. The examples of such ratings will be considered later in this subsection.

The rating of the partners may be made by estimating closeness of their offers to parameters supplied by the initiator of negotiations. In this case, different measures of similarity can be used. They are classified in [14].

$C(S_j, S_k)$ is usually used as the measure of similarity (closeness). Its value is increased as the characteristics of objects became closer. The measure of similarity has the following properties:

$$0 \leq C(S_i, S_j) \leq 1 \text{ for } i \neq j;$$
$$C(S_i, S_j) = 1 \text{ for } i \neq j;$$
$$C(S_i, S_j) = C(S_j, S_i);$$

where S_i, S_j are ranges of tags describing compared objects.

These properties have the sets of equivalent measures represented by the formula:

$$C(S_i, S_j) = \frac{2m(S_i \bigcap S_j)}{(1+u)[m(S_i) + m(S_j) - 2um(S_i \bigcap S_j)]},$$

where $-1 \leq u \leq \infty$, and $m(S_j)$ designates number of elements in the set S_j.

At $u = 0$ we receive a rather frequently used measure of similarity:

$$C(S_i, S_j) = \frac{2m(S \bigcap S_j)}{[m(S_i) + m(S_j)}. \quad (12)$$

It is convenient to calculate the similarity measure for two compared objects against qualitative criteria using a binary matrix with elements $x_{ij} = 1$, if criteria i is satisfied by the object j, and 0 otherwise.

Then (12) looks as follows:

$$C(S_1, S_2) = \frac{2\sum_{i=1}^{1} x_{i1}x_{i2}}{\sum_{i=1}^{1} x_{i1} + \sum_{i=1}^{1} x_{i1}}. \tag{13}$$

When x_{ij} is real or integer, the formula (12) looks as follows:

$$C(S, S) = \frac{2m(s_i \bigcap S_j)}{m(S_i) + m(S_j)} = \frac{2\sum_{i=1}^{1} \min(x_{i1}x_{i2})}{\sum_{i=1}^{1} x_{i1} + \sum_{i=1}^{1} x_{i1}} \tag{14}$$

5.3 Collection of the information describing the partners

Before the beginning of negotiations it is necessary to try to collect maximal information about their participants, their manner of behavior, their strong and weak sides. It may be not only official data of the company, but personal information also, e.g.: whether the offer is unexpected, pioneer, etc., or is not; is there is technical and financial risk; what is experience in implementing similar tasks by the partners in negotiations; which is their financial status; are there similar offers, etc. If the similar offers exist, in what degree are they more favorable than yours? It may be also psychological characteristic of each possible) participant: competence, persistence in achievement of the purpose, his interest in the contract, etc. NSS can present answers to these questions by Tab. 2.

Naturally, list of questions interesting for the manager can be extended according to his interests. NSS structures the obtained information and represents it in a mode convenient for the manager.

5.4 Sifting the offers of the possible partners

The NSS prepares list of offers that do not fulfil conditions formulated by the initiators of negotiations and indicates reasons of their refusal.

The reason may be, e.g.: low value of a measure of similarity obtained by formulas (12) or (13) which specify mismatch of the offers to requests of the customer; unsatisfactory forecast gained by formulas (7), (10), (11); etc. Reason of refusal may be an informal rating made on the basis of the Tab. 2: bad reputation of the firm; competitive business proposition made by other firm; etc.

Table 2

		The possible partners			
		1	2	3	4
1	The offer is pioneer for the possible partners	No	No	No	No
2	Experience of similar tasks implementation for the possible partners	Large	Large	The firm is created recently	There is a small experience
3	Financial status of the possible partners	There were problems	The situation is stable	The firm searches for orders, trying to become stronger in the market	The financial status is satisfactory
4	Are there similar offers from other firms?	No	No	No	No
5	Psychological status: à. Competence	Is competent	Is competent	Is competent	Not highly competent
	b. Persistence	Not highly persistent	Is persistent	Is persistent and aggressive	Unknown
	c. Interest in the contract	Very interested	Moderately interested	Very interested	Very interested

5.5 Finding direction of concessions

It is desirable to concede by a criteria having the least weight. As "weights" of criteria are determined, the NSS specifies by what criteria is preferrable to concede. NSS should estimate results of concessions, e.g., under formulas (2)–(4) or another describing expected result after concessions.

5.6 Determination of concession limits

The limit of concessions can be determined in percents or absolute values of deviations from an original offer, estimating results of deviations according to accepted methods. Limit of concessions can also be determined by economic efficiency, technical limitations, etc.

5.7 Determination of the agreement achievement moment

To determine the moment of purpose achievement the vector of "average" parameters between offers of the negotiators can be used. Certainly it is completely optional for negotiators to stable in the middle, but this vector of "average" values can present some frame at negotiating.

Asterisks in Fig. 2 mark points in sets U^1 and U^2 that are from each other on minimum distance. The point $r1$ is the middle of an interval of aggregating points marked by asterisks and may be used as a pointer to correlated proposal.

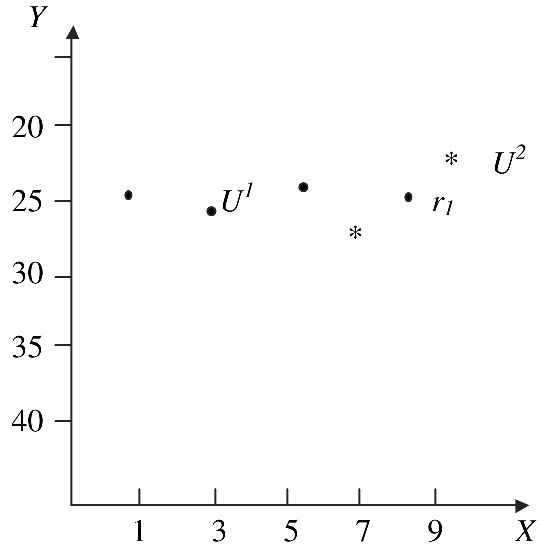

Figure 2

By such reasoning, it is possible to describe the procedure of this point searching as follows.

1. To rate possible decisions by filling on displays of the distributed NSS the table where the criteria and ratings of each point by all criteria are indicated.

2. Distributed NSS selects sets U^i for each manager and represents them in tabular form and/or graphically (similar to Fig. 2).

3. Distributed NSS finds in each set U^i points that are on a minimum distance from each other (similar to points marked with

asterisks in Fig. 2). Generally it is a difficult lookup problem. It can be replaced by finding the "center of gravity" of points from each set U^i:

$$X_i = \frac{1}{n}\sum_{j=1}^{n} x_j,\ Y_i = \frac{1}{n}\sum_{j=1}^{n} y_j,\ \ldots,\ V_i = \frac{1}{n}\sum_{j=1}^{n} \nu_j,$$

where n is the number of points in the set U^i.

In Fig. 2, X axis shows the price of additional production of 1 m^3 of oil, and Y axis gain of oil extracting in %. The points of sets U^1 and U^2 are ratings by the first and second manager of various technologies to increase oil extracting.

Then the system finds "centers of gravity" of all "centers of gravity" of sets U^i retrieved earlier as follows:

$$\tilde{X} = \frac{\sum_{l=1}^{m} \alpha_l x_l}{\sum_{l=1}^{m} \alpha_l},\ \tilde{Y} = \frac{\sum_{l=1}^{m} \alpha_l y_l}{\sum_{l=1}^{m} \alpha_l},\ \ldots,\ \tilde{V} = \frac{\sum_{l=1}^{m} \alpha_l \nu_l}{\sum_{l=1}^{m} \alpha_l}, \qquad (15)$$

where m is the number of managers or experts accepting collective decision, x_l, y_l,...,v_l are coordinates of "center of gravity" of the set U^l, α_l is the "weight" (significance) of the l-th expert. If all experts are of identical influence, $\alpha_i = 1$, $i = 1, 2, \ldots, m$. The found "center of gravity" is similar to the point r_1 in Fig. 2.

4. In the same way system finds "center of gravity" of all retrieved before individual "centers of gravity". Let's designate it r_l^i.

5.8 Choice of negotiating tactics

It is difficult to define tactics of negotiations formally. Nevertheless, the manager or expert can formulate for the NSS some algorithm using which the NSS would propose him the tactics of negotiations. E.g., the NSS can offer using Tab. 2:

- Aggressive tactics, if: 1 (no) $\wedge$ 2 (small experience) $\wedge$ 3 (there were financial problems) $\wedge$ 5à (low) $\wedge$ 5b (is not so persistent) $\wedge$ 5c (is very interested);

- Compromise tactics, if: 1 (yes) $\wedge$ 2 (small experience) $\wedge$ 3 (stable situation) $\wedge$ 4 (no) $\wedge$ 5a (is competent) $\wedge$ 5b (is persistent) $\wedge$ 5c (is interested);

- Compliant tactics, if: 1 (no) $\wedge$ 2 (wide experience) $\wedge$ 3 (stable situation) $\wedge$ 4 (yes) $\wedge$ 5a (highly competent) $\wedge$ 5b (extremely persistent) $\wedge$ (5c (is not so interested) *(the company is extremely interested in getting the order).

Digits in conditions designates numbers of lines in Tab. 2, the linguistic variable in brackets designates the characteristic of the partner, and $*$ specifies the parameter that is absent in Tab. 2. Certainly, the indicated rules are simple enough and carry illustrative character, however rules of credit issue in banks are not more complex. The negotiator can correct the NSS proposals and determine chosen tactics himself.

These conditions are entered in the negotiations support system only once, and then the system automatically parses the table (such as Tab. 2) and issues recommendations that the manager can correct. Tactics listed above or others determine character of functions $\alpha(z)$ and $\beta(z)$ from subsection 2.2.

The procedure of voting is one of manifestations of uncertainty during the decision making. A vivid example of voting procedure influence was demonstrated during the last USA presidential elections, when A. Gor got a majority but did not become the president.

In group decision making, the procedure of voting also can play an essential role. Now theory of voting in small groups (in our case in commissions of experts or managers) is already well established [11] and the paradoxality of some widely applied voting methods is well cleared. Let's demonstrate one of such paradoxes by an example [11]. Let a group consists of 18 experts and should select between three variants of a project. The variant that gained the majority is selected by a rule. Each expert has its own point of view on each variant: the best, relatively worse worse, and absolutely unsuitable. In Tab. 3 we show a possible variant of expert ratings. 7 experts consider that variant A is the best, 6 experts consider B the best, and 5 expert consider C the best. Therefore variant A is selected, though the majority of the experts (11 of 18) consider it absolutely unsuitable.

Table 3

Expert's opinion on projects	Number of experts		
	7	**6**	**5**
The best	A	B	C
Relatively worse	B	C	B
Absolutely unsuitable	C	A	A

Experts can select variants by two methods, by choice or by individual ordering. At a choice method the expert individually selects one or several variants that are the best best from his point of view and discards other variants. At the latter method the procedure is more complex. The expert orders all variants of decision according to his preferences.

NSS can implement collective choice or ordering based on the set of individual choices or orderings. The corresponding voting procedures classification is given in Tab. 4.

Table 4

Form of representation for individual decision	Form of representation for collective decision	
	Collective ordering	**Collective selection**
Individual selection	NSS creates collective ordering from a set of individual selections (selection–ordering)	NSS creates collective selection from a set of individual selections (selection–selection)
Individual ordering	NSS creates collective ordering from a set of individual orderings (ordering–ordering)	NSS creates collective selection from a set of individual orderings (ordering–selection)

Many various procedures of voting are developed now. Unfortunately, we have no possibility to describe them here.

Sometimes the determination of negotiation tactics includes the determination of the possible moment of negotiation termination. Negotiations can be terminated, e.g., at achievement of concession limit, or at the refusal of already achieved agreements, etc.

6 Conducting negotiations

The conduction of negotiations includes obtaining and analysis of the counteroffers the partners, generation of own offers, their rating, and choice of the offer which will be sent to the partners (see Fig. 1, block 4).

To implement effectively computer support in the course it is necessary to offer participating experts a lot of methods they would search the compromise. Many such procedures are now developed. They can be divided roughly into two categories: "pure negotiations" that do not use computer methods, and "man-machine" that are based on computer procedures. The computer procedures applied in practice are in most cases simple enough. the following procedures are indicated in the block 4 in Fig. 1:

1. Obtaining the counteroffers from the partners, their analysis and clarification of negotiation tactics . This procedure repeats items 2 and 8 from block 3.

2. Generation of the possible compromise offers is executed like item 3 of block 2.

3. The rating of the generated offers and selection of the best is executed like item 4 of block 2.

A case is often met when at the preparation of the agreed decision it is necessary to take into account already existing own decisions accepted and defended by each party. In that case not only quality of decisions plays the essential role, but also ambition of managers, lobbied interests, etc. Therefore it is better when it is possible to do not compare decision variants but coordinate procedures of their rating, i.e., algorithms or functions defining quality of decision, "weights" of criteria, characteristics of base scales, etc., predetermining thereby choice of the candidate decision, i.e., executing item 4 of the block 2.

At conduction of negotiations various rating methods for offered decision variants decisions can also be used. Each of the contracting parties can uses its own methods but it is possible to achieve the consent and to use the same method.

As the offers of the manager and his partner do not coincide, it is natural to expect counteroffers of the parties. The NSS can offer some intermediate variant of the coordination drawing points of view of managers nearer. This variant is iterated during negotiations to the acceptance an agreed decision by managers.

The idea of clarification can be illustrated by the following Step 5 being continuation of steps 1–4 of algorithm after Fig. 2.

5. The sequential agreeable iterations are made to the point r_l, or, if it is possible, to the point r_l^i, where l is the number of iteration.

It is possible to consider the point r_l obtained by formula (15) as some “average” point in whose neighborhood an agreed decision can be found and to which the managers want probably to move.

The results in tabular or graphical form are shown by distributed NSS on all manager’s displays. If the compromise resulted in the agreed decision then the coordination procedure is completed. If not, the item 3 from the algorithm repeats resulting the next point r_l^i from proposals of the previous step, and then item 5 repeats. At each iteration it is verified whether the conterminous decisions exist.

The real algorithms of finding of such average point differ certainly from the considered one. Nevertheless search of conditions satisfying negotiators is made by mutual concessions.

6.1 Making agreement

If the agreement is achieved, NSS helps in producing the documents fixing results of negotiations (block 5, Fig. 1).

Conclusion

1. The computer negotiation support system can render the essential help to the negotiators in development of the agreed decision by organizing communication between them, rating of offered variants, generation of the offers and compromise variants.

2. The special efficiency of NSS application appears at the comprehensive approach to the support of negotiations, starting from training conduction of negotiations under NSS and finishing by making the agreement.

3. The uncertainty is an integral accessory of processes of decision making in general and coordination of decisions in particular. The more is the degree of uncertainty, the greater is the value of manager's subjective rating during the negotiarion.

4. The negotiation support system may be an effective tool for negotiators in the course of negotiations if it takes into account subjective interests and preferences of negotiators both at rating of variants, and at coordination of decisions.

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