Modeling the process of intellectual support for optimal decision-making in management systems

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Annotation. The article discusses the construction of an intelligent decision-making system for solving multi-criteria decision-making problems in integrated control systems. The technology for choosing the optimal model and the corresponding method for solving a specific problem are proposed, as well as an integrated model for demonstrating the knowledge base. The issues of building a knowledge base and obtaining an optimal solution using production models are analyzed.

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Analysis of the problem of building intelligent decision support systems

The rapid development of computer technology creates new opportunities in the field of constructing normative decision-making methods. In this regard, there appeared such a direction of research as the development of intelligent decision support systems (IDSS). These systems are aimed at combining decision-making methods and procedures and the capabilities of modern computing technology, which can significantly improve the existing decision-making practice.

At present, intelligent DSS's attract many researchers for several reasons. First of all, a certain stage has been passed in the use of computers in the tasks of organizational management. Firstly, the reasons for the unsuccessful use of automated control systems (ACS) to meet the needs of managers - decision makers (DM), became clearer in making specific decisions. Second, evidence has accumulated about the insufficient use of models built specifically for decision-making problems. Obviously, it is impossible to obtain in full all the objective information necessary for their successful application. Therefore, such models are subject to the subjective assumptions of their creators. This is the reason for the decision maker's refusal to use such models in real decision-making situations. Thirdly, to date, there are data from numerous psychological studies of the decision-making capabilities of decision-makers. It turned out that the capabilities of the human information processing system are quite limited. The decision-maker needs to be helped by organizing the process of obtaining information in a special way.

All these reasons have objectively determined the need for systems that combine the capabilities of modern computers and a person's ability to make rational decisions.[1]

Thus, in intelligent decision support systems, approaches are combined on a common basis, which are typical for the following areas of research:

- making decisions;
- extraction and presentation of knowledge;
- construction of human-machine (dialogue) systems;
- building information systems.

The synergistic interaction of methods belonging to these four areas makes intelligent decision support systems a qualitatively new means of decision support. The following definition can be given to decision support systems. Decision support systems are human-machine systems that enable decision makers to use data, knowledge, objective and subjective models to analyze and solve semi-structured and unstructured problems.

In accordance with the semi-structured tasks are those that contain both quantitative and qualitative variables, and the qualitative aspects of the problem tend to dominate. Unstructured problems have only a qualitative description.

The conceptual model of a decision support system corresponding to this definition is shown in Fig. 1. The “user-system”**(I)** interface contains means for generating dialog control. The blocks of problem analysis and decision making (DM) include procedures and methods that allow to formulate the problem posed using databases (DB), model base (MB) and knowledge base (KB), analyze the possibilities of its solution and obtain a result. The IDSS also includes tools for extracting data and knowledge, building models and manipulating them.

Decision support systems, which until now have been widely used to manage corporate activities, are coming into information technology management systems.

The decision support system is used to solve the following interrelated problems of information technology management:

- setting up hardware and software, taking into account the current distribution of loads in the network;
- making decisions on the modernization of hardware and software, taking into account the current state of technical progress, information about manufacturers and suppliers of hardware and software and the comparative characteristics of these products;
- modernization management;
- modeling the operation of existing networks.

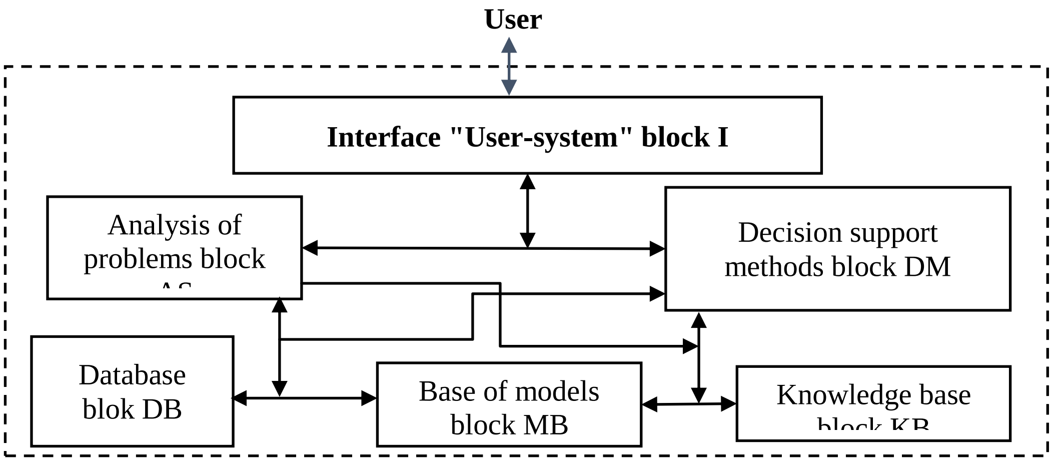
The problem of making a decision in the management of network information technologies is reduced to the choice of such a mode of operation of a corporate computer network, which would provide a given quality (response time, performance, availability) of the application software (AS).

This task is poorly formalized in view of its following specific properties: multicriteria of decisions made (criteria are used: reaction time, productivity, availability); availability of quantitative and qualitative assessments (scales) by criteria; methods use various optimization concepts (ways to find a solution); the object of management is a distributed network information technology (NIT).

The process of forming and choosing decisions requires the complex use of modern mathematical models and methods, a decision support system and a structure of decision makerspreferences. The construction and use of decision-making models requires an understanding of the essence and conditions of the tasks being solved; methodologies and technologies for developing models; mathematical means and accounting for the system of preferences of decision makers; knowledge and experience of developers.

In these conditions, it is advisable to use IDSS to improve the efficiency of management of the SIT. Currently, there are a significant number of systems for various purposes. Proceeding from the specifics of the problems of the domain management of the NIT, we will be interested in the DSS in terms of multi-criteria.

All this speaks of the relevance and practical importance of developing such decision support systems for solving problems of various subject area, the need for a broader and more focused consideration of the subject area specifics, the creation of systems with broad functionality and a developed user interface.



Technology for choosing a method for solving a decision problem

The issues of building an intelligent decision support system (IDSS) for solving multi-criteria problems were considered in the works of domestic and foreign authors. There are a number of problems, among which the most important is the problem of the correspondence between the already structured task and the method of decision making. This problem can be solved by creating a knowledge base of an experienced consultant and a library of decision-making methods. In addition, difficulties are caused by the process of structuring the task due to the presence of non-formalized factors, as well as the organization of the correct way of obtaining information from the decision maker.[2]

Correctness is understood as the ability of the decision maker to determine the course of the dialogue and receive explanations at each stage of the dialogue.

In this regard, it seems urgent to develop a technology and build a knowledge base of IDSS for choosing a method for solving multicriteria problems.

The technology of choosing the optimal model and the corresponding method for solving a specific problem for a decision maker who is an expert in the subject area, but unfamiliar with mathematical methods is proposed.[3]

This technology consists in the step-by-step clarification of the DM's views by means of his answers to the questions proposed by the system. Receiving information from the decision maker is carried out in a flexible dialogue mode, when the decision maker himself chooses different dialogue options from the menu.

It should be noted the activity of the system in relation to the user (ready-made sets of criteria, constraints and decision variables are offered), which reduces the number of errors on the part of the decision maker.

In general, the interactive dialogue process of formalizing the decision maker's preference system and choosing a solution method is represented as a sequence of stages.

The elements (parameters) of the complex multicriteria model are used as the initial data with which the technology operates, namely: the situation prevailing at the time of decision making, optimality criteria, a system of constraints, a set of decision variables, a decision maker's preference system. At the end of the technology, it is required to obtain a specific method for solving the problem.[4]

Step 1. Selecting task parameters.

1. Selection of a set (set, type) of criteria $\{f_i\}$.

2. Choice of a set of constraints: functional $g_i(x)$and criterial$j_i(x)$.

3. Choice of a set of decision variables $x\{i\}$:

- infinite, determined by the constraints $g_i(x) \leq b$;
- final $\{x_1,\ x_2, \dots, x_n\}$.

Step 2. Determination of attitudes towards the importance of criteria.On the basis of the decision maker's answers, the importance of the criteria is specified.

Step 3. Setting the values of the restrictions.

1. Setting the values of criterial constraints:

- criteria that are optimized $f_i(x) \geq< k_1$, where $i \in \{n+1 \dots N\}$.

2. Setting the values of functional constraints $g_i(x) \leq b = Const,\ g_i(x) \geq< b + \Delta b$.

Step 4. Choice of the principle of optimality φ_1, where $i = 1, \dots, n$.

The optimality principle is a formalized expression of the decision maker's preferences and is the principle of comparing multicriteria (vector) estimates in the method used.

Step 5. Selecting the task class.One of four classes of problems is selected, namely: based on the existence of a utility function, based on the principle of satisfaction, based on the concept of optimization at the desired point, based on the principle of achievement.

Step 6. Choosing a specific method for solving the problem.

At the first, second and third stages, the initial formalization of the problem is performed by determining the system of preferences of the decision maker through his answers to the questions proposed by the system.

At the fourth, fifth and sixth stages, the choice of the principle of optimality, the type of problem and a specific method for solving the problem is carried out.

Typical methods for solving this class of problems are proposed, namely: the weighted convolution method and the ideal point method guarantee the achievement of a Pareto-optimal solution in problems based on the existence of a utility function and problems based on the concept of optimization at the desired point, respectively; the method of concessions and the method of system optimization guarantee solutions that are closest to satisfactory ones in the problems of choosing a satisfactory solution and in the problems of purposeful formation of feasible solutions with a varied structure of constraints, respectively.

The second, fourth, fifth and sixth stages are implemented as a procedure, which is shown in Fig. 2.

This technology has a number of advantages:

- a wider set of parameters of the complex multicriteria model is taken into account;
- a more accurate display of the decision maker's preference system is carried out (by taking into account a wider set of parameters);
- the selected complex multicriteria model, on the one hand, more adequately reflects the subject areaproblem, ets.objective parameters, on the other hand, the decision maker's preference system is more adequately displayed, ets.subjective parameters.
- the chosen method and the implemented algorithm give the best solution (mode of operation of the computer network).[6,7]

Development of a knowledge base used to select a method for solving a multicriteria problem

General structure of IDSS. Currently, there is a fairly large set of decision support systems that successfully implement many tasks in various areas, however, the acquisition of a decision support system for widespread use requires significant financial costs, and bringing them to the end user is additional effective management of the NIT. Therefore, it is more expedient to develop an integrated decision support system, which is quite powerful, flexible, adaptive, covering a wide range of decision-making methods and capable of providing effective assistance to decision makers in managing NIT.

The creation of IDSS is the development of mathematical, information and software tools that provide assistance to decision makers based on the accumulated and computerized knowledge of experts in conjunction with mathematical models of controlled processes.

When controlling the NIT, both discrete problems are solved on a finite set of alternatives, and problems of mathematical programming. There are a significant number of methods for solving them. However, it should be noted the low efficiency of the use by end users of mathematical methods of decision-making in real situations. In addition, the study of the subject areas of problems of management of network information technologies made it possible to highlight their main properties:

- large volumes of qualitative and quantitative data on tasks of varying degrees of formalization;
- significant dynamism of emerging situations;
- The decision maker, when making decisions, proceeds from his own often subjective ideas about the subject area;
- the presence of a different level of preparedness of the decision maker.

Under these conditions, a promising approach to improving the efficiency of network information technology management is the creation of IDSS, including the knowledge contained in mathematical models and methods, and the knowledge contained in the experience of qualified specialists.

The structure of the developed system in relation to the control of the NIT is shown in Fig.3.

A conceptual model of a decision support system described in Fig. 1.

The decision maker is the administrator of the computer network.

An expert is an experienced specialist in a specific subject area as well as an expert in mathematical models.

The IDSS structure contains the following blocks:

The dialogue interface supports the dialogue of the system with the user in a natural-limited language. Search tasks, formulation of a problem, choice of a solution method, structuring of initial information are carried out in a dialogue mode. The user is prompted for each of the questions.

The block of explanations provides an explanation of the conclusions and allows you to trace the chain of "reasoning" IDSS (decoding the logic of obtaining a solution), as well as to interfere with the user in the course of solving the problem.

The block of knowledge replenishment carries out the construction of rules; maintaining and updating the knowledge base; provides support for the strength and relevance of the knowledge base by eliminating outdated and imperfect rules, introducing new ones.

The database contains information describing the objects of the subject area, dynamically changing in the process of solving the problem. Datacanbebothquantitativeandqualitative.

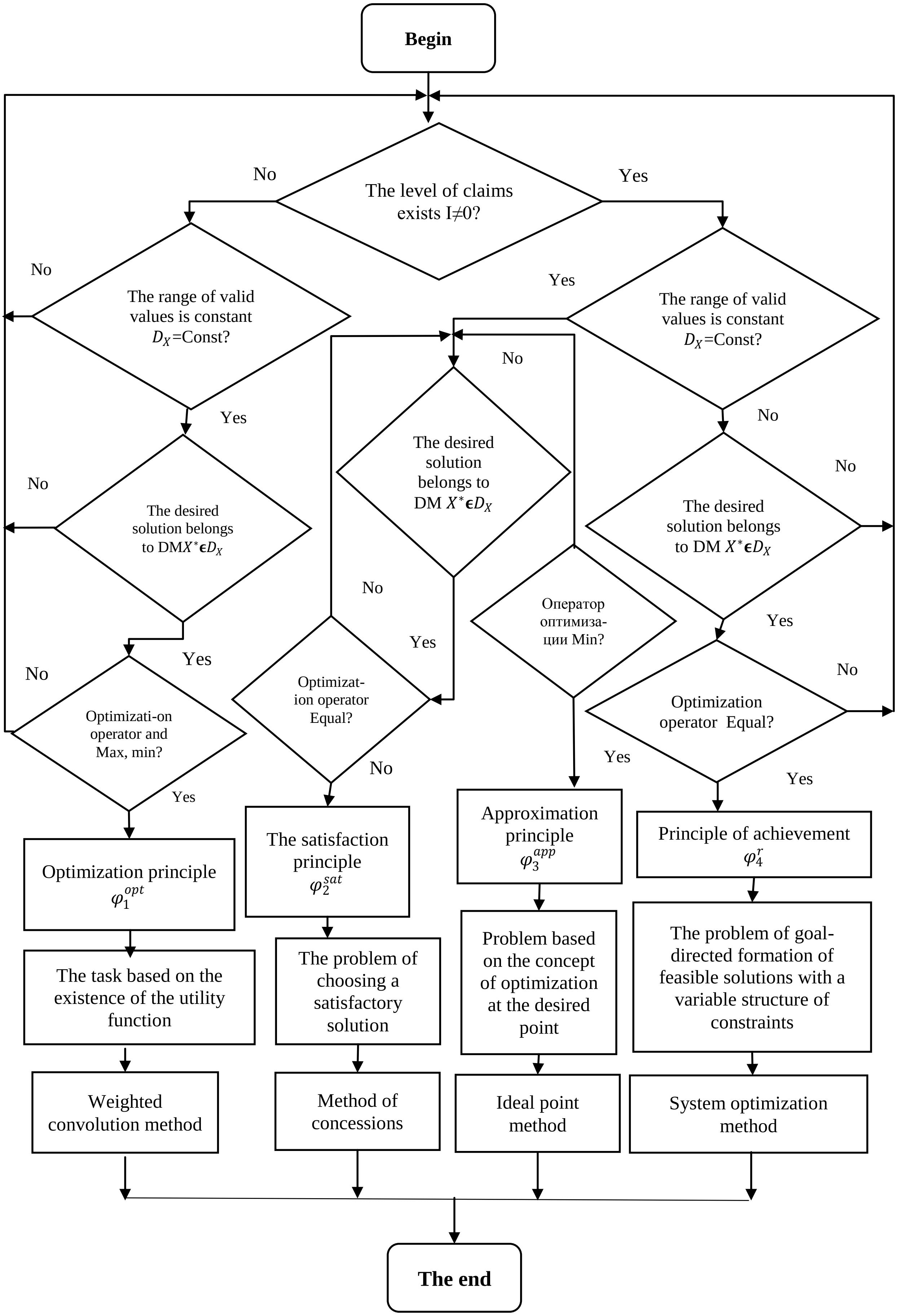
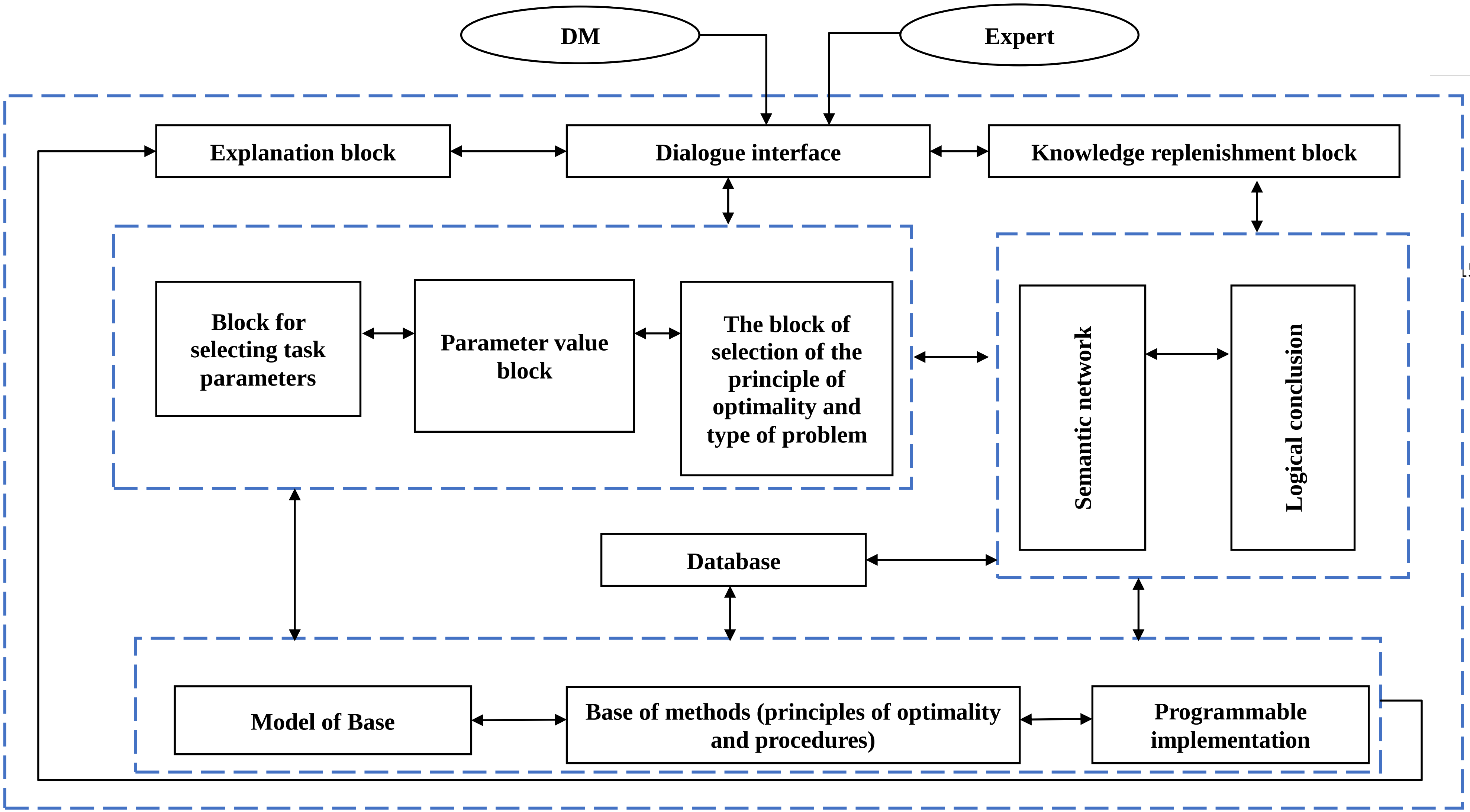


Figure: 2. The procedure for choosing a specific method for solving the problem


DM
Expert
Explanation block
Dialogue interface
Knowledge replenishment block
Block for selecting task parameters
Parameter value block
The block of selection of the principle of optimality and type of problem
Semantic network
Logical conclusion
Database
Model of Base
Base of methods (principles of optimality and procedures)
Programmable implementation

Knowledge base is a domain model containing formalized knowledge of specialists in the form of sets of heuristic rules; meta-rules that determine the strategy for managing heuristic rules during the implementation of the main functions of the IDSS; information about the structure and content of the database. The knowledge base includes a semantic map and inference (fact base and rule base).

By a semantic map we mean a directed graph, the nodes of which represent the microexpert system, and the arcs represent the technology for solving the problem.

The fact base contains information (data) about the specific state of the parameter of the problem being solved.

The rule base contains a set of rules that convey the logic of the expert's reasoning and uses his subjective heuristic knowledge.

Logical inference is a logical and mathematical apparatus that searches for a solution and obtains a plausible conclusion based on knowledge base and database data.

The block of formalization of the decision maker's preferences system is designed to identify the decision maker's preferences when choosing a method and procedure for solving a multicriteria problem. This block includes a block for selecting the parameters of the problem, a block for setting parameter values, a block for choosing the principle of optimality and the type of problem.[10]

The block for selecting the problem parameters determines the sets of criteria, functional and criterion constraints, and decision variables.

The block for setting the parameter values determines the attitude of the decision maker to the importance of the criteria and provides the input of the values of the selected parameters of the problem.

The block for choosing the principle of optimality and the type of problem forms the choice of the principle of optimality, the type of problem and a specific method of solution based on the information received from the decision maker.

The solution planner provides formalization of the problem by automatic synthesis from typical elements of the system of models and recording it in a form suitable for processing by software packages.

The solution planner includes a model base, a method base (optimality principles and procedures), and a software implementation.

The base of models is the base of typical, repeatedly used models that formalize the problem being solved.

The base of methods (principles of optimality and procedures) contains standard, repeatedly used solution methods (principles of optimality), as well as procedures that implement methods for solving problems.

Software implementation - software solution of the following tasks:

1) choosing a specific method for solving the problem;

2) implementation of any of the four methods (weighted convolution method, concession method, ideal point method, system optimization method);

3) interpretation of the results of solving the problem for the decision maker.

In the developed structure, in addition to the general (typical) blocks of the DSS conceptual model, specific blocks are used that determine the distinctive feature of the described structure.

This structure has several advantages:

- the presence of a block for formalizing the decision maker's preference system (for an adequate display of the decision maker's preferences);
- the presence of a solution planning block (software and mathematical block);
- the presence of a block of knowledge base, including a combined model of knowledge representation, consisting of three models: a semantic map, production rules and frames.

The block of formalization of the decision maker's preferences system is aimed at identifying the decision maker's preferences depending on the current situation, which is represented by a set of specific parameters of the state of a computer network.

The decision planning block has a wide range of mathematical tools, allows solving multi-criteria problems with quantitative and qualitative criteria scales.

The IDSS knowledge base block, based on the dialogue of the system with the decision maker about the subject area and the preference system, carries out: automation of the construction of a mathematical model of the problem being solved, automation of the process of choosing the necessary solution method and, accordingly, its implementation procedure, setting the necessary parameters of the solution search algorithm, interpretation of the decision maker of the results.

Representation of knowledge in the knowledge base of IDSS. Let us consider in more detail the knowledge base of the developed IDSS, containing the rules (presented earlier in the technology in the form of procedures) for choosing methods and assessing preferences.

Knowledge representation methods are traditionally divided into 4 classes: semantic maps, logical approaches, frames and production systems.

Semantic maps are graphical diagrams with nodes connected by arcs. Nodes represent concepts, and arcs represent relationships between them.

The advantage of this presentation method is its openness, which means that new nodes and links can be added where needed. Another feature of the Semantic map is property inheritance, i.e. each node can inherit properties of its associated nodes.

An important advantage of semantic maps is that they are built from simple elements that are combined around nodes that correspond to given concepts. This property allows us to consider semantic maps a better tool for representing knowledge than direct use of predicate calculus.

The production system is formed by a set of rules, which are that if some given condition is met, then a certain action can be performed.

The production system can be represented as the following model:

$$PS = \langle F, P, I \rangle, \quad (1)$$

where$F$ is a database containing constants and current variables; P is a knowledge base containing many facts and rules; I is an interpreter that implements inference procedures.

$$I = \langle V, S, R, W \rangle, \quad (2)$$

where V is a selection process that selects from P a subset of active rules (productions) used at this stage of work, and a subset of active data from F; S − the process of drawing up rules and data; R − conflict resolution process (planning process), which determines which of the rules will be applicable at this stage of work; W − theprocess of implementing this rule.

The production rules are as follows:

$$IF(A\ and\ B or C), then\ D\ and\ F\ and\ G, \quad (3)$$

whereA, B, C are some conditions, and D, F, G are some actions. On the left side of the rule, any combination of function words is possible and, or, their number is not limited, although in practice it is extremely rare to be large. The number of service words in the right part is also not limited.[11]

The principle of operation of the production system is as follows: the product (rule), the condition of which turns out to be true for the current state of knowledge base and database, is fulfilled. In this case, the executed rule activates the data located in the specified database structure; the execution of the rules continues until all of them are executed or the stop rule comes into effect.

The production system is the most convenient form of knowledge representation.

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Production rules facilitate the formation of explanations, the results of conclusions and calculations. They can handle unplanned but rewarding interactions. In other words, they can use their portion of knowledge when needed.

Frames occupy a special place among the methods of knowledge representation

Nowadays, frames have found their place for representing knowledge in artificial intelligence systems. Frames are seen as a means of organizing knowledge. Although frames can include active components (for example, in the form of attached procedures), they are mostly passive data structures on which external procedures are defined.

The knowledge base frame representation, as well as the semantic map method, allows for fast inference based on the principle of inheritance.

However, it is difficult to give clear recommendations defining the preference of any method of knowledge representation for classes of expert systems. In practice, the choice of the type of knowledge representation is often related to the developer's habit and the type of shell used (knowledge representation language and interpreter).

Most of the existing intelligent systems for representing and processing knowledge ("SAS System", "Oracle Express", "Unisys") use production rules and less often ("Hybrid", "GP SYS") combined models of knowledge representation.

The obvious advantages of the combined knowledge representation model are that it more adequately corresponds to the specific properties of the displayed tasks and the capabilities of the decision maker, and also provides more efficient knowledge processing.

The knowledge that describes the general technology (task) of decision-making in information technology management is presented in the form of a semantic map, the elements of which are microexpert systems. Each microexpert system controls certain parameters and solves its own narrow problem according to its own criteria of optimality, and when developing a complex solution, these particular solutions are coordinated. Thus, a distributed decision support system is created.

This IDSS is functionally distributed, i.e. includes various microexpert systems, connected by information and installed on one computer (they are spatially concentrated).

In view of the multidimensionality of the mapping of the real semantic map of the search for a solution, only certain fragments of the semantic map and the distributed expert system for choosing a method for solving the problem (the principle of optimality) are presented.

In the next example (Fig. 4), the choice of the optimality principle (solution method) is carried out using four rules.

Rule 1
$If P^U = 1 \wedge P^D=1 \wedge P^X = 1 \rightarrow \text{Optimisation} \rightarrow \phi^{opt}$
Rule 2
$If P^U = 0 \wedge P^D=1 \wedge P^X = 1 \rightarrow \text{Equality} \rightarrow \phi^{r}$
Rule 3
$If P^U = 0 \wedge P^D=0 \wedge P^X = 0 \rightarrow \text{Minimization} \rightarrow \phi^{app}$
Rule 4
$If P^U = 0 \wedge P^D=0 \wedge P^X = 1 \rightarrow \text{Equality} \rightarrow \phi^{sat}$

Figure: 4. Fragment of a set of production rules that selects the optimality principle (solution method)

In this example, the following notation is used: P - rule; φ^{opt} - optimization principle; φ^{r} - the principle of achievement; φ^{app} - approximation principle; ϕ^{sat} is the satisfaction principle.

A fragment of the production rule in terms of the subject area when choosing a method is presented as follows: if (the number of criteria is more than two) and (the scales of criteria are quantitative) and (the decision maker has an area of desired criterion values) and (the area is expressed by levels of aspiration/sufficiency), then the method is selected interval target programming.

A fragment of a distributed expert system for choosing the principle of optimality is shown in Fig. five.

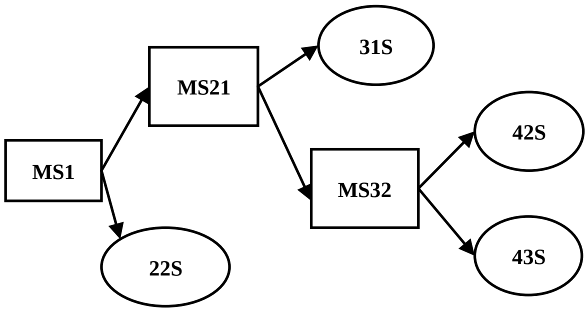

Figure: 5. Fragment of a distributed expert system for choosing the principle of optimality

S —the state of the model element;

MS - microexpert system.

A fragment of the semantic map for choosing the optimality principle is shown in Fig. 6.

The following notationsare used:

U —the presence of a level of claims (desired criterion values);

D_x —area of admissible solutions;

x^* —decision variables;

S —the state of the model element;

Max, Min —optimization (maximization, minimization) of target functions;

$Equal$ —satisfaction of the desired or achievable directive values of the criteria;

Min —minimization of deviations from the desired criterion values.

Frames are presented in the form of tables containing data on the specific state of the parameter of the problem being solved. The structure of the frames of the semantic map for choosing the principle of optimality is shown in Fig. 7.

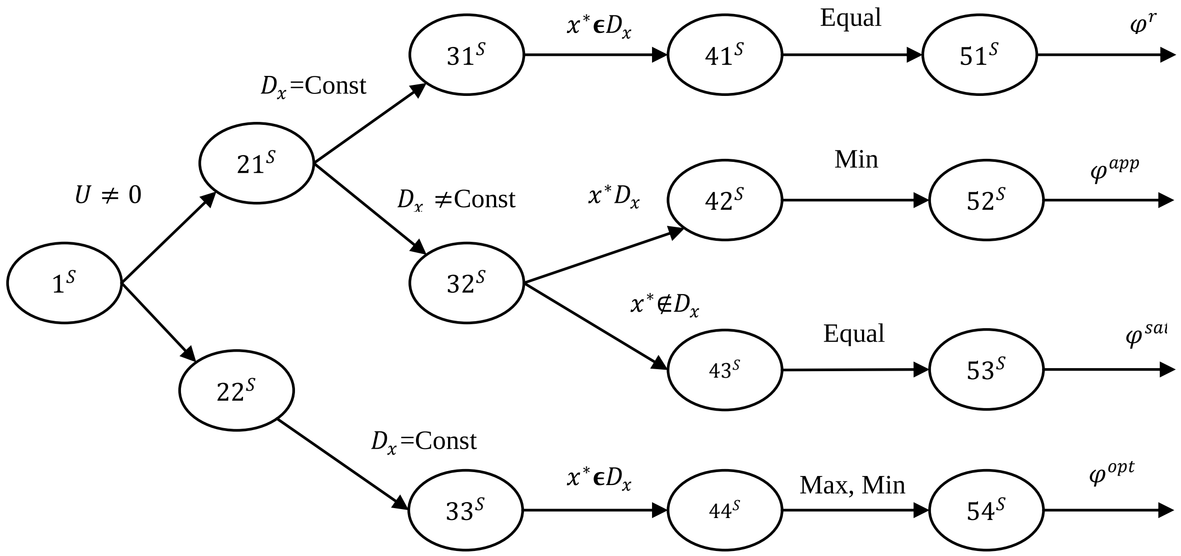

Figure: 6. Fragment of the semantic map for choosing the principle of optimality

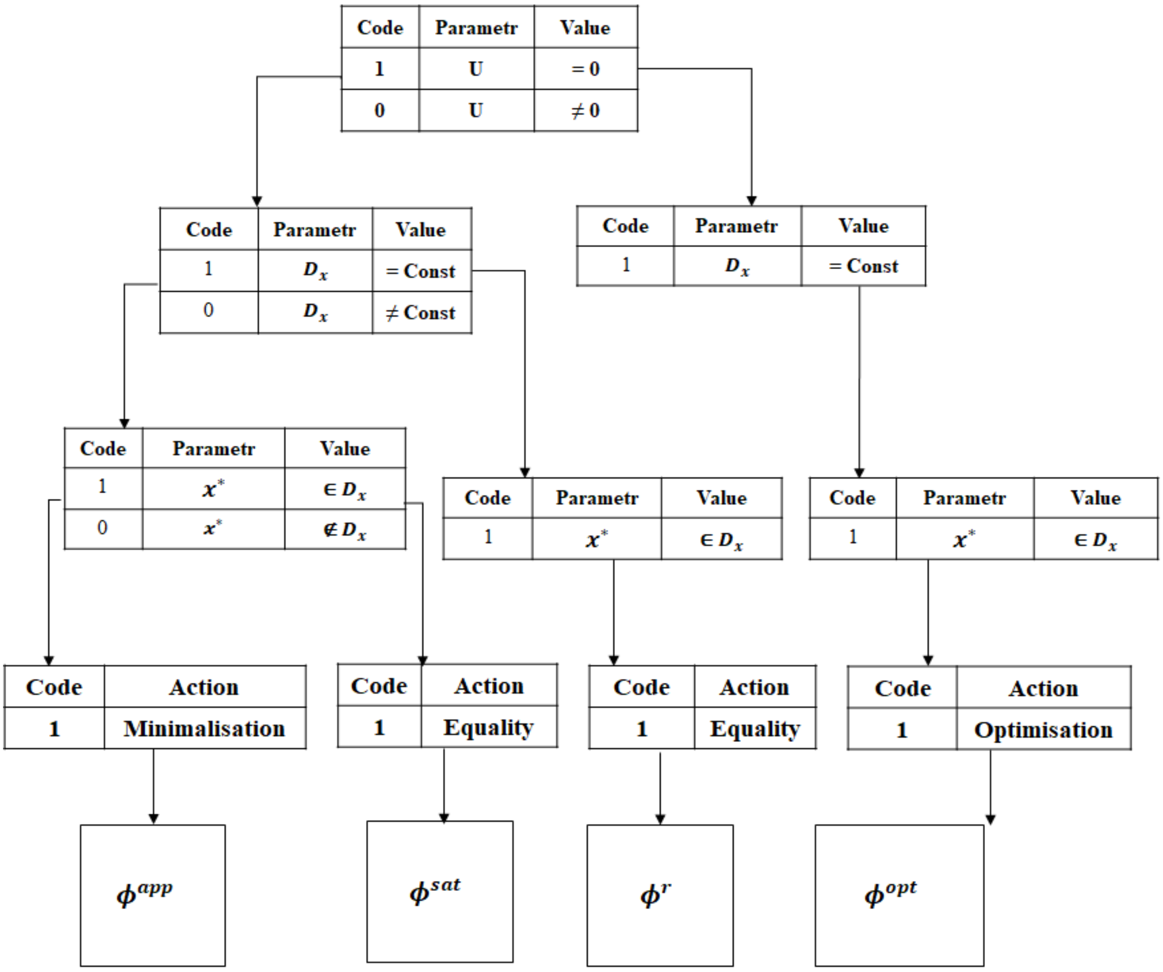

Fig. 7. Fragment of the structure of frames of the semantic map for choosing the principle of optimality

The distributed expert system consists of micro-expert systems capable of performing limited intellectual functions (for example, choosing one of two options) when solving particular problems, taking into account the preferences of the decision maker.

A distributed expert system is a part of the database IDSS knowledge base, capable of coordinating and managing a multitude of microexpert systems to solve a common task (controlling the modes of functioning of a computer network).

Program implementation of results

Object-oriented languages are a large class of languages that have recently become used for programming in the field of artificial intelligence and have proven themselves well.

Examples of object oriented languages are Smalltalk, C ++, Java. The object-oriented extensions LIPS (CLOS - General Object-Oriented LIPS - system) and PROLOGUE (L&O - Logic and Objects) are also used. The use of object-oriented technologies (due to simplified creation of classes and easier programming for clients of classes) can achieve significant performance gains in software development.

To implement the technology, which is an interactive dialogue process of forming a system of preferences of a decision maker and choosing a method for solving a problem, the IDSS must provide:

- dialogue with the user in a convenient graphical form (graphical interface);
- platform independence (portability);
- checking user information for consistency;

- analysis of the conditions of the problem and its assignment to one of the typical classes (recognition of its type);

- comparison of the assigned task to one of the models from the bank of models;

- reduction of restrictions to a standard form for using the selected solution algorithm;

- selection of one of the solution methods, implemented algorithmically and selected from the available bank of algorithms;

- interpretation of the results obtained.

The choice of the programming language was carried out according to two requirements, namely: the ability to convey the logic of reasoning of the decision maker and to implement mathematical expressions.

For the software implementation of the results presented in the article, the object-oriented language JAVA was chosen, since it provides tools for creating a graphical interface, is platform-independent, and provides an object model for data manipulation.

Another argument in favor of JAVA is that this programming language provides a set of libraries for generating and reading

XML documents. XML format that is suggested to be chosen for representing knowledge in the IDSS knowledge base, since XML (Extensible Markup Language) is extensible and portable.

Conclusion

1. The technology of choosing the optimal model and the corresponding method for solving a specific problem is proposed for a decision maker who is an expert in the subject area, but is not familiar with mathematical methods.

This technology has several advantages:

- a wider set of parameters of the complex multicriteria model is taken into account;

- a more accurate display of the decision maker's preference system is carried out (by taking into account a wider set of parameters);

- the selected complex multicriteria model, on the one hand, more adequately reflects the SbA problem, i.e. objective parameters, on the other hand, the decision maker's preference system is more adequately displayed, etc. subjective parameters;

- the chosen method and the implemented algorithm give the best solution (mode of operation of the computer network).

2. The IDSS has been developed, which allows to implement all the stages of the technology of choosing a method for solving the problem of making a decision in the management of NIT.

NIT control - selection of the best version of the NIT mode, which would ensure the specified quality (response time, productivity, availability) of the application software (AS).

In contrast to the existing decision support system used to manage the NIT (Tax authorities of Republic of Uzbekistan), which provide statistical data on the state of the computer network, the proposed system is focused on making decisions (recommendations) on choosing the best mode of NIT management for a specific applicationsoftware.

The system is aimed at a user - a computer network administrator who has knowledge of a specific subject area, but is not familiar with mathematical methods.

IDSS allows:

- to improve the efficiency of decisions made by using optimization methods;

- to increase the efficiency of decisions made by providing timely information to users;

- to reduce the risks associated with errors and incorrect strategic decisions of the user.

3. To represent knowledge in KB it is proposed to use a combined model of knowledge representation, which includes a semantic map, production rules and frames.

This combined model has important advantages, namely: it more adequately corresponds to the specific properties of the displayed tasks and the capabilities of the decision maker, and also provides more efficient knowledge processing.

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