Method for Finding a Plan for Solving Mathematical Problems as Component of Information Technology

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Abstract. In article the concept of use of innovative technology of study on the basis of information and cognitive model of activation of processes of study of leading experts, as intellectual agents in system of support of acceptance of administrative decisions, for different subject areas is proved. As a result of research it is improved two-level model of the organization of management of educational institution which provides activation of processes of study for intellectual activity of the expert during the decision of put problem problems, what provide a finding of optimum decisions, as means of systematization of administrative decisions of the own experimental-scientific organization and practical work. The offered system-structural method which is directed on activation of processes of study of experts during finds of optimum decisions by mathematical methods which consist in research of objects as set of elements and relations between them for preparation and a substantiation of strategic decisions concerning not structured difficult problems that exist or arise in information system during its working out or functioning. The method of structuration of procedures of mathematical and applied problems solving and revealing of their information essence, and also the offered method of search of the plan of mathematical problems solving as components of information technology is detailed. decisions.

Keywords: method; model; problem; solving mathematical problems; information technologies.

1 Introduction

In order to choose the method [1] of solving problems, it is important to know what type of problems and on the basis of what general rules and regulations it is possible to know its solution, which needs a solution plan. Finding a solution plan is an intellectual process, which is based on information and mathematical operations and procedures for performing target actions. A problem solving plan is a central part of the whole decision-making process, which leads to an algorithm that consists of actions and operations, which are studied in basic courses of mathematics and logic of the subject industry [10, 22]. The process of problem solving begins not with a plan, but with analysis, construction of a schematic record (formalization), identification of conditions and goal, search for a solution scenario and a plan scheme based on the associative generation of the idea of achieving the goal as components of a cognitive model of thinking of a specialist [20]. The basis of cognitive activity during the identification of the type of tasks is the process of recognition on the basis of the procedure of structuration, classification of conditions and images, purpose and types of mathematical tasks with reference models of decision procedures [12]. The analysis of classes of models of problems testifies that process of construction of methods and plans of the decision in the implicit form uses components of information technology [19, 24]. New requirements of science, technics, business processes have formed classes of problems which cannot be untied without use of information technology, their software and computer software. Information and computer technologies is a system of integral complementary technologies with a certain hierarchy and structure of dialogue between the user and the computer system. Accordingly, there are regularities and methods of data creation as data carriers about the state of the object (information), storage, search, methods of selection, elaboration and representation, received from other structures [4, 6, 7]. During the solution of formulated mathematical problems data are numbers, logical and mathematical expressions, geometric structures, which are processed according to algorithms. Solving problems of information type, they operate with data which have different structure, both mathematical and linguistic, and are connected with information search, working out of unstructured text information (editing, translation, planning) [2, 3, 9, 28]. Besides, computer and applied software gives the chance to store and process nonnumeric information - texts, drawings, graphics, lists and tables. The basic psychological, cognitive and intellectual properties necessary for functioning of a face in the environment of information technologies: high level of mobility and ability to work virtually; psychological and cognitive firmness for work in extreme conditions; high level of education and mental abilities, logical and analytical thinking; ability to solve non-standard problems and creativity of decisions; skills and abilities for transformation of knowledge and their use for the decision of problems and problem situations; uniqueness of in [16, 18, 23]. The concept of innovative technology of studying on the basis of use of information and cognitive model for activation of processes of studying, as the intellectual agent in system of support of decision-making is proved. The two-level model of the organization of management of an educational institution which provides activation of processes of study for intellectual activity of the expert in the decision of set problem tasks which provide scientific researches and means of systematization of own organization of experimental-scientific and practical work is improved. The offered system-structural method is directed on activation of processes of study of experts that consists in research [15, 26] of objects as set of elements and relations between them for preparation and substantiation of strategic decisions concerning not structured problems which exist or arise in information system. The method of structuration of procedures of mathematical and applied problems solving and revealing of their information essence, and also the method of search of the plan of mathematical problems solving as components of information technology is detailed [9, 13].

2 Consolidated model for collective decision-making with discussion

To choose a method for solving problems, it is important to know what type of tasks and on the basis of what general rules and regulations you can know its solution, which needs a solution plan [25, 27, 32, 33].

Finding a solution plan is an intellectual process that is based on information and mathematical operations and procedures for performing targeted actions. A plan for solving a problem is a central part of the entire decision-making process, which leads to an algorithm that consists of actions and operations that are studied in basic courses in mathematics and logic in the subject field [5, 11, 25, 31].

The process of solving problems does not begin with a plan, but from analysis, constructing a schematic record (formalization), identifying conditions and goals, searching for a solution scenario and a plan based on the associative generation of an idea to achieve a goal as a component of a specialist's cognitive model of thinking.

Classification of task types

The basis of cognitive activity during the allocation of the type of tasks is the recognition process based on the structuring procedure, classification of conditions and images, goals and types of mathematical problems with reference models of decision procedures.

Basic reference task models:

- problems on search, recognition of the search unknown (object, value, shape, geometric structure), and also on the solution of equations, systems of equations, inequalities, finding of variables concerning conditions;
- problem of finishing or explanation – in problems of this type of requirement consists in finding or checking the validity of the statement, its correctness or incorrectness, to explain a certain fact;
- problems on construction or transformation – in such problems for construction of decision process it is necessary to transform mathematical expression for revealing of structure, to construct a geometrical figure according to conditions and the purpose.

The analysis of classes of problem models shows that the process of constructing methods and solutions of the solution in the implicit form uses components of information technology:

- cognitive models of goal-oriented thinking;
- ability to use data and knowledge presented in mathematical form;
- the presence of the principles of logical thinking to present the content of knowledge and operate them;

- ability to move from the formula to the algorithm as a plan of operations;
- identifying and memorizing the essence and content of the task and performing its decomposition;
- memorization of data, mathematical operations, schemes of construction of the plan of the decision;
- identification of the information essence of the problem and the purpose of its solution and the choice of tool (logical-mathematical) for the construction of the plan and its implementation.

Types of tasks that require information and computer technology

New requirements of science, technology, business processes have formed classes of problems that cannot be solved without the use of information technology, their software and computer software [17].

The following tasks are characterized by:

- a large amount of unstructured data;
- software for building algorithms;
- planning decision-making procedures;
- the need for databases and knowledge in a particular subject area;
- complexity, blurred data and unclear goals in decision making;
- large volume and speed of data exchange required in the process of solving problems.

Information and computer technologies are a system of integral complementary technologies with a certain hierarchy and structure of user dialogue with a computer system.

Definitions. Informatics is a branch of scientific and technical activity of a person, which includes the structure and general properties of data and their transformation, the identification of the content necessary for targeted decisions.

Accordingly, patterns and methods of data creation as carriers of information about the state of the object (information), storage, retrieval, methods of selection, processing and presentation obtained from other structures are revealed.

Information technology is a set of hardware and software tools for collecting, processing, interpreting data content and their interpretation, providing decision-making processes in industry, management, science, education, design of complex systems, economics, medicine, energy, ecology, during the formation of plans solving specific tasks for each industry and further formation of requirements [8, 21].

Information is information about objects and phenomena in the environment and man-made systems, their parameters, properties, which characterize the state described by a set of ordered data.

When solving the formulated mathematical problems, the data are numbers, logical and mathematical expressions, geometric structures, which are processed according to algorithms.

Solving problems of information type, operate with data that have a different structure – both mathematical and linguistic, and related to information retrieval, processing of unstructured textual information (editing, translation, planning), and computer and application software provides the ability to store and process non-numerical information – texts, figures, graphics, lists and tables [30, 31].

The standard course in computer science, computer engineering and computer technology consists of the following educational subject-oriented blocks (units): basics of computer science (mathematical and logical); operating systems (OS); work in the Windows environment; basics of algorithm theory; basics of programming in high-level languages, code programming; structures of algorithms (logical and mathematical operations, cycles, trees); programming of the interface for communication of a component and dialogue; text procedures for processing linguistic structures, Microsoft Word; spreadsheets, Microsoft Excel; databases and their administration; computer graphics and multimedia; systems for creating presentations and automatic processing of data and documents; photo and image processing; computer networks and the Internet.

Information technology is the basis for creating complex information systems to solve problems of complex systems management and is the basis for the formation and support of decision-making. Accordingly, they include: hardware and software; artificial intelligence systems; expert systems; systems for supporting targeted decision-making in conditions of risks and conflicts; information systems for production management; internet technologies and telecommunication systems; virtual reality systems; game systems and multimedia; knowledge engineering systems; databases and knowledge; integrated information platforms; automated learning systems; computer-aided design systems.

Requirements for employees in the field of information technology and the educational process, involve the possession of knowledge that depends on the state and development of public information technology.

The main psychological, cognitive and intellectual properties required for the functioning of a person in the environment of information technology: a high level of mobility and the ability to work virtually; psychological and cognitive resilience to work in extreme conditions; high level of education and mental abilities, logical and analytical thinking; ability to solve non-standard problems and creativity of decisions; skills and abilities to transform knowledge and use it to solve problems and problem situations; uniqueness of individual knowledge; ability to generate ideas and hypotheses to develop management strategies.

These requirements are the basis for the creation of new methods of staff training for IT systems based on the use of modern information and computer technology.

3 Logical components in the process of solving problems

Deductive findings and evidence

In deductive conclusions, new conclusions from the source data are formed on the basis of the rules of logic and the theory of set.

Definitions. Evidence rule:

$\Pi D \stackrel{\Delta}{=}$ ⟨If a link is proved and has a certain structure, the conclusion that has such a structure is proven ⟩; that is:

- the structure of complex statements is considered, not the structure of elementary statements;

– statements (conclusions) are based on logical links between statements, not content.

Example of a logical conclusion process:

$$A_i = \{X_{i1}, X_{i2} \dots X_{in}\} \tag{1}$$

$$A_1, A_2 \dots A_n \mapsto B \tag{2}$$

If the statements are true with the structure expressed in formulas $A_1, A_2 \dots A_n$, then true B with its structure, provided that the identical truth is the formula for the logic of statements:

$$\frac{A_1, A_2 \dots A_n}{B} \equiv A_1, A_2 \dots A_n \vdash B \tag{3}$$

$$\vDash A_1, A_2 \dots A_n \Longrightarrow B; \text{ або } \vDash \bigwedge_{i=1}^{n} A_i \Longrightarrow B, \tag{4}$$

that is, in the correct conclusion, there is a ratio of logical progression:

$$\vDash \left(\bigwedge_{i=1}^{n} A_i \Longrightarrow B \right) \equiv T, \qquad T \vDash \left(\bigwedge_{i=1}^{n} A_i, \exists A_i = \phi \Longrightarrow B \right) \equiv F. \tag{5}$$

The assessment of the correctness of the conclusion is based on procedures:

1. Formalize references and conclusions.
2. Formulate the conjuncture of references.
3. Determine the validity of the reference formulas.

Contingent evidence. Rule modus ponens:

$$\frac{A \to B, A}{B} \quad \Big| \quad \big((A \Longrightarrow B) \to B\big) \quad \Big| \tag{6}$$

Output rule options (π_{mp}):

$$\pi_{mp}^1 : \frac{A \to B, A}{B}; \quad \pi_{mp}^2 : \frac{A \to B, A}{\sim B}; \tag{7}$$

$$\pi_{mp}^3 : \frac{\sim A \to B, \sim A}{B}; \quad \pi_{mp}^4 : \frac{\sim A \to \sim B, \sim A}{\sim B}; \tag{8}$$

where π^i – is the rule; A – links, B – the consequence of the output procedure;

but

$$\pi_v : \frac{A \to B, B}{A} \tag{9}$$

is not a rule of withdrawal?

Negative conditional category syllogism (modus tollens) for output rules:

$$\pi_{mt} : \frac{A \to B, \sim B}{\sim A} \to T; \quad (((A \to B) \wedge \sim B) \to \sim A) - output; \tag{10}$$

$$\pi_{mt} : \frac{A \to B, \sim A}{\sim B} \to F; ((A \to B) \wedge \sim A \to \sim B) - output. \tag{11}$$

In the process of analysis of meaningful expressions, if – (modus tollens) under the scheme of conditional-categorical syllogism, then on the content the statement expresses necessary and sufficient conditions, that is interpreted as double implication:

$$\pi_v: \frac{A\to B,\sim A}{\sim B} \;\to\; T, \tag{12}$$

$$to\ wit\ \ \frac{A\leftrightarrow B,\sim A}{\sim B}\ \ gives\ the\ formula:\ \langle((\,A \leftrightarrow B)\wedge\sim A) \to \sim B\rangle, \tag{13}$$

reflecting the structure of logical relationships.

Conclusion to double implication binds the truth of logical statements, if (A↔B), then:

$$\pi_{v1}: \frac{A\leftrightarrow B,A}{B}; \quad \pi_{v2}: \frac{A\leftrightarrow B,B}{A}; \tag{14}$$

$$\pi_{v3}: \frac{A\leftrightarrow B,\sim A}{\sim B}; \quad \pi_{v4}: \frac{A\leftrightarrow B,\sim B}{\sim A}. \tag{15}$$

The scheme of conditional syllogism conclusion in mathematical proof procedures has the following form: if (A and B) true statements:

$$\frac{A\to B,B\to C}{A\to C}, \quad \langle(A \to B)\wedge(B \to C) \to (A \to C) \to T\rangle, \tag{16}$$

where T – is always true, so we have rules of conclusion:

$$\pi_{v1}: \frac{A\to B,\sim A\to C}{\sim B\to C}; \quad \pi_{v2}: \frac{A\to B,\sim A\to C}{\sim C\to B}; \tag{17}$$

$$\pi_{v3}: \frac{A\to B,C\to\sim B}{A\to\sim C}; \quad \pi_{v4}: \frac{A\to B,C\to\sim B}{C\to\sim A}. \tag{18}$$

Disjunctive syllogisms (separately categorical) - the modus tollendo ponens is used in procedures for solving problems:

$$\frac{A\vee B,\sim A}{B}, \quad ie \quad (((A \vee B)\wedge\sim A) \to B); \tag{19}$$

respectively, we have the following rules:

$$\pi_{v1}: \frac{A\vee B,\sim B}{A}; \qquad \pi_{v2}: \frac{\sim A\vee B,A}{AB}; \qquad \pi_{v3}: \frac{A\vee B,B}{A}. \tag{20}$$

There can be complex structures for rules:

$$\pi_v: \left\langle\frac{A\vee B\vee C,\sim A\wedge\sim B}{C}\right\rangle, \qquad \pi_v: \left\langle\frac{A\vee B,A}{\sim B}\right\rangle \equiv \big((A \vee B)\wedge A\big) \to \sim B, \tag{21}$$

i.e. in disjunctions all alternative forces should be considered, which exist in conditions of correctly formulated tasks.

Dilemmas are conditionally separating conditions in which the snares consist of two or more conditions and one separating condition (double prediction), i.e. two alternatives and two undesirables for the subject, this is the basis for choosing a solution when solving complex problems for selection procedures.

A simple constructive *dilemma:*

$$\pi_{vD1}: \left\langle\frac{A\to B,C\to B,A\vee C}{B}\right\rangle, \tag{22}$$

respectively, tautology has the appearance

$$\big((A \to B)\wedge(C \to B)\wedge(A \to C) \to B\big)TTf. \tag{23}$$

A complex *structural dilemma in the evidentiary procedure:*

$$\pi_{vD2}: \left\langle \frac{A\to B, C\to B, A\vee C}{B\vee D} \right\rangle, \tag{24}$$

respectively, tautology has the appearance

$$\langle (A \to B)\wedge(C \to D)\wedge(A \to C) \vee (B \vee D)\rangle TTf. \tag{25}$$

A simple destructive dilemma in output rules:

$$\pi_{vD3}: \left\langle \frac{A\to B, A\to C, \sim B\vee\sim C}{\sim A} \right\rangle, \tag{26}$$

then we have:

$$\big((A \to B)\wedge(A \to C)\wedge(\sim B \vee C) \to \sim A\big). \tag{27}$$

A complex destructive dilemma is used to build plans and decision trees:

$$\pi_{vD4}: \left\langle \frac{A\to B, C\to D, \sim B\vee\sim D}{\sim A\vee\sim C} \right\rangle. \tag{28}$$

The law of contraposition (conditional conclusion) in the procedures of comparing the plans of problem solving has the form:

$$\pi_{vD5}: \left\langle \frac{A\to B}{\sim B\to\sim A} \right\rangle, \qquad \big((A \to B) \to (\sim B \to \sim A)\big); \tag{29}$$

$$\pi_{vD6}: \left\langle \frac{A\to B, C\to D, A\wedge C}{B\wedge D} \right\rangle, \qquad \pi_{vD7}: \left\langle \frac{A\to B, C\to D, \sim B\wedge\sim D}{\sim A\wedge\sim C} \right\rangle. \tag{30}$$

The law of contraposition is the basis for checking the variants of solution plans for inconsistency with the task condition.

The problem of the conclusion of all the consequences according to the given forces, which have elementary statements.

Structure of hypotheses: with the hypothesis of the formula £2 is formula £1, for which (£1 ⟶ £2) – is always true, then, accordingly, we prepare logical formulas, which are the basis for building procedures for solving logical and mathematical problems.

Accordingly:

$$(A \to B)\wedge A \quad \vdash \quad \begin{array}{l} a)\ \sim A \vee B \\ b)\ A \vee B \\ c)\ A \vee \sim B \\ d)\ (\sim A \vee B) \wedge (A \vee B) \\ e)\ (\sim A \vee B) \wedge (A \vee \sim B) \\ t)\ (A \vee B) \wedge (A \vee \sim B) \\ g)\ (\sim A \vee B) \wedge (A \vee \sim B) \wedge (A \vee \sim B) \end{array} \tag{31}$$

Direct and indirect evidence in the process of problem solving

Proof is a thinking process that aims to justify the truth of a statement with the help of other related statements whose truth has been established.

The rule of correct conclusion (modus ponens) formal proof is constructed in the form of consecutive logical actions:

$$\pi_v : \frac{B \to C, B}{C}; \qquad A \to B, B \to C, A \mapsto C. \tag{32}$$

$$\pi_v : \frac{\sim C \to \sim B, B}{C};$$

1) *A→B*
2) *B→C*
3) *A* – true
4) *B* – obtained from 1, 3; *C* – obtained from 2, 4.

Abstracts of evidence are formulated in conditional statements:

If: $(B \to C)$ is the result of the conjunctive algorithm $(A_1 \wedge A_2 \wedge \ldots \wedge A_n)$, that is: $A_1 \wedge A_2 \wedge \ldots \wedge A_n \ \mapsto (B \to C)$, that is $(B \to C)$ is a conclusion, i.e. the method of conclusion is that B is an assumption and *C* is derived:

$$A_1 \wedge A_2 \wedge \ldots \wedge A_n \ \mapsto (B \to C) \equiv A_1 \wedge A_2 \wedge \ldots \wedge A_n \tag{34}$$

Proof of the formula: $\big((A \to B) \wedge (B \to C)\big) \to (A \to C),$ (35)

the assumptions:

1) $(A \to B) \wedge (B \to C)$
2) $(A \to B)$ – type of conjunction
3) *A* – true assumption
4) *B* – received <u>*(modus ponens)*</u> з 2, 3
5) $(B \to C)$ – type of conjunction, *C* – received <u>*(modus ponens)*</u> is 4, 5.

<u>Analytical tables in problem solving procedures</u>

<u>The tables are built on the basis of the rules of truth determination based on indexing through *T* - true, *F* - false. Let us consider the truth of statements of this conclusion:</u>

1) $$A \wedge B; \left\langle \frac{T \wedge B}{\begin{matrix} TA \\ TB \end{matrix}} \right\rangle,$$

(36)

2) $$A \wedge B; \left\langle F_\wedge \equiv \frac{F(A \wedge B)}{FA \,|\, FB} \right\rangle,$$ Assessment of the situation when the expression:

3) $$A \vee B; \left\langle T_{\vee}: \frac{T(A \vee B)}{TA \mid TB} \right\rangle, \left\langle F_{\vee}: \frac{F(A \vee B)}{\begin{matrix} FA \\ FB \end{matrix}} \right\rangle,$$

$(A \vee B) \to (A \wedge B)$

Is most formal:

$(A \vee B) \to (A \wedge B)$

$T \vee F \to T \wedge F$

T – true,

F – false.

4) $$A \to B; \left\langle T_{\to}: \frac{T(A \to B)}{FA \mid TB} \right\rangle, \left\langle F_{\to}: \frac{F(A \to B)}{\begin{matrix} TA \\ FB \end{matrix}} \right\rangle,$$

5) $$(\sim A); \left\langle \frac{T(\sim A)}{FA} : T\sim \right\rangle, \left\langle \frac{F(\sim A)}{TA} : F\sim \right\rangle.$$

<u>Conclusion of categorical statements</u>

Simple statements have an internal structure that plays a role in the analysis of statements, i.e.

$\langle \frac{S,P}{deadlines} \rangle$:

S – the subject is what the statement says;

P – the predicate is what's claimed about the subject.;

$\langle P, S \rangle$ – is categorical;

$\langle PRS \rangle$ – is a lot of terms between which relationships are established, and they are not easy, that is: $\langle \forall P, \exists R, \exists S \left\{ P \overset{R}{\to} S \right\}, \rho \neq 0, s \neq \phi \rangle$;

$\langle S \in P \rangle$ – affirmative;

$\langle S$ не $\in P \rangle$ – contradictory.

Classification of categorical statements:

A – in general affirmative: $A(S, P)$;

E – in general contradictory: $E(S, P)$;

I – part affirmative: $I(S, P)$;

O – part contradictory: $O(S, P)$.

<u>*The terms are distributed* (S^+, P^+)*:*</u> if it is fully included in the volume of another term or completely excluded from it [14];

<u>*Times unallocated* (S^-, P^-)*:*</u> if it is partially included in or out of the volume of another term.

<u>Mutual counter-narrative or excluded counter-narrative statements cannot be together</u>:

$$TT: \langle A(s, \rho)\ or\ O(s, \rho) \rangle \to F; \tag{37}$$

true, but may be false:

$$TT: \langle E(s,\rho)\ or\ I(s,\rho)\rangle \rightarrow F. \tag{38}$$

<u>Contradictory statements</u>: I – incompatible statements, if they cannot be true at the same time, but can be at the same time:

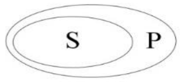
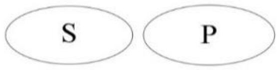
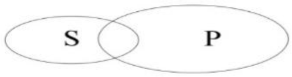
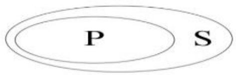
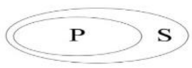
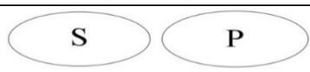
$$TT: \langle \big(A(s,\rho)\big)\ \mathrm{i}\ \big(E(s,\rho)\big)\rangle \rightarrow F; \tag{39}$$

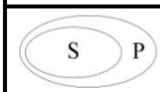
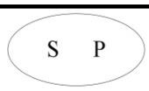
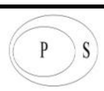
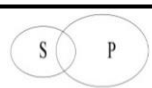
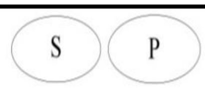
subcontracted ∧ - statements can be true at the same time, but they cannot be false at the same time:

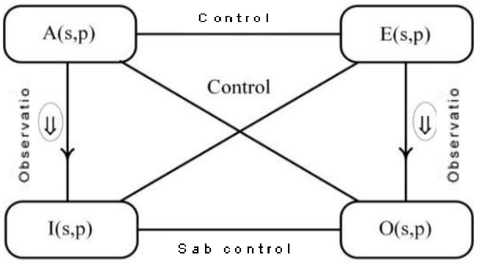
$$\exists T: \langle \big(I(s,\rho)\big)\ \wedge O(s,\rho)\rangle \rightarrow TF. \tag{40}$$

Multiple concepts of logical diagrams are given in Table 1.

Table 1.

Marking	Mathematical representa-tion	Euler's diagram	Distribution
A(s,ρ)	$\forall S\ \subset\ P$ $\forall_x \in S$ $X \in P$	 	S^+, P^- S^+, P^+
E(s,ρ)	$\forall_x \epsilon S$ $X \notin P$		S^+, P^+
T(s,ρ)	$\exists_x \epsilon S$ $X \epsilon\ P$		S^-, P^- S^-, P^-
I(s,ρ)	$\exists_x \epsilon S$ $X \epsilon\ P$		S^-, P^+ S^-, P^+
O(s,ρ)	$\exists S, \exists_x \epsilon S$ $X \notin P$		S^-, P^+
	$\exists X_s \epsilon S$ $X_s \notin P$		S^-, P^+
	$\exists X_k \epsilon S$ $X_k \notin P$		S^-, P^+

				
*A(s,ρ)**	*A(sρ)*	*A(ρ,s)*	*I(s,ρ)**	*E(sρ)**
I(s,ρ)	*A(ρ,s)*	*I(s,ρ)*	*I(ρ,s)*	*E(ρ,s)*
I(ρ,s)	*I(sρ)*	*I(ρ,s)*	*O(s,ρ)*	*O(s,ρ)*
O(s,ρ)	*I(ρ,s)*	*O(s,ρ)**	*O(ρ,s)*	*O(ρ,s)*
***— incompatibility**				

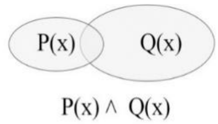
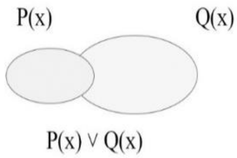
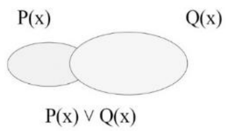
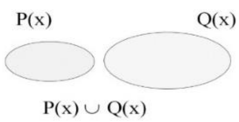
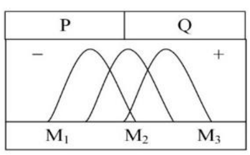


The relation in the logical square is the basis for the formation of the content in the structure of statements in accordance with a set of concepts represented through predicate forms (Fig. 1).

Fig. 1. Relationships in the logical square

Operations on predicates defined on the set M:(P,Q,R) ≡ $\{P(x), Q(x), R(x),\ x\epsilon M\}$, filed in Tables 2.

Table 2.

Mathematical representation		**Visual representation, diagrams**
$\big(P(x)\wedge Q(x)\big)\to T$	$\exists_x\epsilon M, P(x)T_sQ(x)\to T$	
$\big(P(x)\vee Q(x)\big)\to T$ $P(x)\wedge\sim\big(Q(x)\big)\to T$ $\big(\sim P(x)\wedge Q(x)\big)\to T$	$\exists_x\epsilon M, P(x)\to T\ or\ \ Q(x)\to T$ $\exists_x\epsilon M, P(x)\to F\ or\ \ Q(x)\to T$ $\exists_x\epsilon M, P(x)\to T\ or\ \ Q(x)\to F$	
$P(x)\to Q(x)\to F$ $P(x)\to Q(x)\to T$ $\sim P(x)\vee Q(x)$	$\exists_x\epsilon M, P(x)\to T\ or\ \ Q(x)\to F$ $\frac{\forall_x\epsilon M, P(x)\to T}{\sim P(x)\vee Q(x)}\wedge\ Q(x)\to T$	
$P(x)\leftrightarrow Q(x)\to T$	$\big(P(x)\wedge Q(x)\big)\to T$ $\big(P(x)\wedge Q(x)\big)\to F$	
$\exists_xP(x), \forall_xP(x)$	*Quainter operators*	
	Fuzzy membership of sets on M_i	

Predicate operations

Predicate as a logical form of statement about an object – P(x), which is defined on set M, will be true if:

$$\forall_x \epsilon M, \exists_x P(x) \to T; \quad (41)$$

$$\forall_x \epsilon M, \sim P(x) \to F; \quad (42)$$

$$M_T^1(\sim P) \vee M_T^1(P) = M. \quad (43)$$

For different P, Q on set M define complex predicates:

1) $P(x) \wedge Q(x): \exists_x \epsilon M: P(x) \to T \wedge Q(x) \to T;$ (44)
2) $P(x) \vee Q(x): \exists_x \epsilon M: P(x) \to T \vee Q(x) \to T,$ (45)
   $or\ \ P(x) \wedge \sim Q(x)$ i $\sim P(x) \wedge Q(x);$
3) $P(x) \implies Q(x),\ \exists_x \epsilon M,\ \big(P(x) \to T \implies Q(x)\big) \Longmapsto T,$ (46)
   $\exists_x \epsilon M,\ (P(x) \to T \implies Q(x) \to F) \Longmapsto F;$
4) $P(x) \leftrightarrow Q(x),\ \exists_x \epsilon M,\ (P(x) \to T \wedge Q(x) \to T) \longmapsto T,$ (47)
   $\exists_x \epsilon M,\ (P(x) \to F \wedge Q(x) \to F) \longmapsto T,$
   $\exists_x \epsilon M,\ (P(x) \to T \wedge Q(x) \to F) \longmapsto F.$

Quantification of double predictors $P(x, y)$:

1) $\forall_x\ \forall_y\ P(x, y);$ (48)
2) $\forall_y\ \forall_x\ P(x, y);$
3) $\exists_x\ \exists_y\ P(x, y);$
4) $\exists_y\ \exists_x\ P(x, y);$
5) $\forall_y\ \exists_x\ P(x, y);$
6) $\exists_x\ \forall_y\ P(x, y);$
7) $\forall_x\ \exists_y\ P(x, y);$
8) $\exists_y\ \forall_x\ P(x, y).$

Partial quantification:

$$\forall_x\big[(x \neq 0) \wedge (y = 0) \implies \exists_y \exists_z (x = y \cdot z)\big]. \quad (49)$$

For the logic of predicates, equivalence is based on $(£_1 \equiv £_2) \implies (£_1 \leftrightarrow £_2)$ – ta tology, that is, always true:

$$\big(P_1(x) \leftrightarrow P_2(x)\big) \equiv \forall_x\big(P_1(x) \leftrightarrow P_2(x)\big). \quad (50)$$

To establish the truth in L_p builds an interpretation and truth estimation table for $\big(P_1(x) \leftrightarrow P_2(x)\big)$, a complex predicate:

1) $(£_1 \Longmapsto £_2)$ – only when there's a socially [29] significant implication $£_2$ is $£_1$, $(£_1 \implies £_2)$:

$$P_1(x) \implies P_2(x) \equiv \forall_x\big(P_1(x) \to P_2(x)\big); \quad (51)$$

2) representation *of the category of statements through predicates*:

$$A(Any \_\_ \ is \ \_\_),\ \ A(Any\ S\ is\ P),\ \ \forall_x\big(S(x) \to P(x)\big); \quad (52)$$

$$E(Not\ one \_\_ \ is \ \_\_),\ \ E(Not\ one\ S\ is\ P),\ \ \forall_x\big(S(x) \to \sim P(x)\big);$$

$$I(Some\ \_\_is\_\_),\ \ I\ (Some\ S\ is\ P),\ \ \exists_x\big(S(x) \wedge P(x)\big);$$

$$O(Not\ some\ \_\_is\_\_),\ \ O(Not\ some\ \ S\ is\ P),\ \ \exists_x\big(S(x) \wedge P(x)\big).$$

The selection of single elements by quantifiers in logical and mathematical statements $\left(\exists_x P(x)\right)$ is based on:

$$\forall_x \forall_y\left[\left(P(x) \wedge P(y)\right) \Rightarrow (x = y)\right]; \quad (53)$$
$$\exists_x P(x) \wedge \forall_x \forall_y [P(x) \wedge P(y) \rightarrow (x = y)];$$
$$\exists_x \exists_y\left[\left(P(x) \wedge P(y)\right) \rightarrow (x \neq y)\right];$$
$$\forall_x \forall_y \forall_z\left[\left(P(x) \wedge P(y) \wedge P(z)\right) \Rightarrow (z = x) \vee (z = y)\right].$$

<u>Hypotheses</u>

Logical structure of the problem solution scheme formation. The hypothesis of the formula $£_2$ is $£_1$, for which ($£_1 \rightarrow £_2$) - the formula is always true.

<u>Example:</u> $£_2(A \leftrightarrow B)$*;*
what hypotheses might be:

$$(A \leftrightarrow B) \equiv (A \wedge B) \vee (\sim A \vee \sim B); \quad (54)$$
$$\sim(A \leftrightarrow B) \equiv (\sim A \vee B) \wedge (A \vee B);$$

$then\ £_1\ maybe$:

$$(A \leftrightarrow B) \wedge (\sim A \vee \sim B); \quad (55)$$
$$(A \leftrightarrow B) \wedge (A \vee B);$$
$$(A \leftrightarrow B) \wedge (\sim A \vee \sim B) \wedge (A \vee B);$$

<u>Proof</u>

The proof is the logical competence of the methods of finding a solution to a problem:

(Proof) $\triangleq$ Arguments Procedure Thesis	Thinking process that aims to justify the truth of a statement based on other statements whose truth has already been established (proven).

The withdrawal rules are based on:

$$\pi_{v\ MP}\colon \frac{B \rightarrow C, B}{C} - \ withdrawal\ rule, \quad (56)$$

$$\pi_{v\ MP}\colon \frac{\sim C \rightarrow \sim B, B}{C}; \quad (57)$$

formal rule making (π_i) is the basis for building diagrams, plans and decision trees, which are included in information technology tools:

$$\langle A \rightarrow B, B \rightarrow C, A \mapsto C \rangle, \quad (58)$$

$A \rightarrow B$
$B \rightarrow C$ | *arguments*
A

B *got* $(A \rightarrow B) \wedge A$ | $\mapsto C$.
C *got* $(B \rightarrow C) \wedge B$

To build strategies and plans for solving problems, it is necessary to generate ideas on which it is possible to build solution trees and problem trees based on the generation of hypotheses about a possible scheme for achieving the goal of solving the problem.

Conclusions

The concept of innovative technology of training on the basis of use of information and cognitive model for activation of processes of studying, as the intellectual agent in system of support of decision-making is proved. The two-level model of the organization of management of educational institution which provides activation of processes of training for intellectual activity of the expert in the decision of the set problem tasks which provide scientific researches and means of systematization of the own organization of experimental-scientific and practical work is improved. The offered system-structural method is directed on activation of processes of training of experts that consists in research of objects as set of elements and relations between them for preparation and substantiation of strategic decisions concerning not structured problems which exist or arise in information system. The method of structuration of procedures of mathematical and applied problems solving and revealing of their information essence, and also the method of search of plan of mathematical problems solving as components of information technology is detailed.

References

[1] J. Wang et al., "A High-Tolerance Matching Method Against Load Fluctuation for Ultrasonic Transducers," *in IEEE Transactions on Power Electronics*, vol. 35, no. 1, pp. 1147-1155, Jan. 2020, doi: 10.1109/TPEL.2019.2921384.

[2] A. Rathinam and S. Padmini, "Composite Counterpropagation Neural Networks for Solving Power Flow Problem," *International Conference on Computational Intelligence and Multimedia Applications (ICCIMA 2007)*, Sivakasi, Tamil Nadu, 2007, pp. 212-216, doi: 10.1109/ICCIMA.2007.348.

[3] Gengqian Liu, Tiejun Li, Yuqing Peng and Xiangdan Hou, "The Ant Algorithm for Solving Robot Path Planning Problem," *Third International Conference on Information Technology and Applications (ICITA'05)*, Sydney, NSW, 2005, pp. 25-27, doi: 10.1109/ICITA.2005.268.

[4] S. Fan, Q. Gong, S. You, J. Hou, Y. Chen and L. Li, "Path planning method for flight vehicle between two consecutive nodes," *2016 IEEE Chinese Guidance, Navigation and Control Conference (CGNCC)*, Nanjing, 2016, pp. 2406-2410, doi: 10.1109/CGNCC.2016.7829169.

[5] M. T. A. P. Wickramarathna and N. Wickramaarachchi, "Transmission Network Planning Using Genetic Algorithm," *2006 IEEE/PES Transmission & Distribution Conference and Exposition: Latin America, Caracas*, 2006, pp. 1-5, doi: 10.1109/TDCLA.2006.311550.

[6] Y. Luo, X. Huang and B. Zeng, "Forward Displacement Analysis of the 4SPS-2CCS Generalized Stewart Platform Based on Hyper-Chaotic Neural Network Mathematical Programming Method," *2008 The 9th International Conference for Young Computer Scientists, Hunan*, 2008, pp. 2857-2862, doi: 10.1109/ICYCS.2008.24.

[7] A. Rathinam, S. Padmini and V. Ravikumar, "Application of supervised learning artificial neural networks [CPNN, BPNN] for solving power flow problem," *2007 IET-UK International Conference on Information and Communication Technology in Electrical Sciences (ICTES 2007)*, Tamil Nadu, 2007, pp. 156-160.

[8] Dronyuk I., Fedevych O. and Lipinski P. Ateb-prediction simulation of traffic using OMNeT++ modeling tools. *Computer Sciences and Information Technologies - Proceedings of the 11-th International Scientific and Technical Conference, CSIT2016*, 2016, pp. 96-98.

[9] W. Li, "An Improved Artificial Potential Field Method Based on Chaos Theory for UAV Route Planning," *2019 34rd Youth Academic Annual Conference of Chinese Association of Automation (YAC)*, Jinzhou, China, 2019, pp. 47-51, doi: 10.1109/YAC.2019.8787671.

[10] Y. Rashkevych, D. Peleshko and M. Pasyeka Optimization search process in database of learning system, *IEEE International Workshop on Intelligent data acquisition and advanced computing systems: technology and application*, 2003, pp. 358-361

[11] Zechun Hu and Furong Li, "Network expansion planning considering N-1 security criterion by iterative mixed-integer programming approach," *IEEE PES General Meeting, Providence*, RI, 2010, pp. 1-6, doi: 10.1109/PES.2010.5589271.

[12] N. Pasyeka, H. Mykhailyshyn and M. Pasyeka Development Algorithmic Model for Optimization of Distributed Fault-Tolerant Web-Systems, *IEEE International Scientific-Practical Conference «Problems of Infocommunications. Science and Technology»*, 9–12 October, 2018, Kharkiv, pp. 663–669

[13] Dronyuk I. and Fedevych O. (2017) Traffic Flows Ateb-Prediction Method with Fluctuation Modeling Using Dirac Functions. In: Gaj P., Kwiecień A., Sawicki M. (eds) Computer Networks. CN 2017. Communications in Computer and Information Science, vol 718. Springer, Cham p.3-13 https://doi.org/10.1007/978-3-319-59767-6_1

[14] Y. Rashkevych., D. Peleshko, M. Pasyeka and A. Stetsyuk Design of web-oriented distributed learning systems. Upravlyayushchie Sistemy i Mashiny, Issue 3-4, 2002, pp. 72–80

[15] M. Gorbachuk, A. Lazor, V. Bandyra and M. Pasyeka Method and Parallelization Algorithms of Synthesis of Empirical Models Taking Into Account the Measurement Errors, *International scientific and technical conference «Experience in the development and applica-tion of instrumental CAD in microelectronics»*, 2015, pp. 319–327

[16] Medykovsky M., Droniuk I., Nazarkevych M. and Fedevych O. Modelling the Pertubation of Traffic Based on Ateb-functions. CN 2013. Communications in Computer and Information Science, vol 370, 2013. Springer, Berlin, Heidelberg https://doi.org/10.1007/978-3-642-38865-1_5

[17] T. Hovorushchenko and O. Pavlova Intelligent system for determining the sufficiency of metric information in the software requirements specifications. *CMIS2019*, 2019, pp. 253-266

[18] T. Hovorushchenko, O. Pavlova and A. Boyarchuk Modeling of nonfunctional characteristics of the software for selection of accurate scope of Information for their evaluation. DCSMart 2019: pp. 206-216.

[19] I. Dronyuk, I. Moiseienko, and Jan Greguš. Analysis of Creative Industries Activities in European Union Countries. *The International Workshop on Digitalization and Servitization within Factory-Free Economy (D&SwFFE 2019)* November 4-7, 2019, Coimbra, Portugal Procedia Computer Science 160 pp. 479–484, 2019.

[20] Logoyda, M., Nazarkevych, M., Voznyi, Y., Dmytruk, S., & Smotr, O. Identification of Biometric Images using Latent Elements. *CEUR Workshop Proceedings.* 2019, P. 12.

[21] Nazarkevych, M., Logoyda, M., Troyan, O., Vozniy, Y., & Shpak, Z. The Ateb-Gabor Filter for Fingerprinting. *In International Conference on Computer Science and Information Technology*, 2019, pp. 247-255. Springer, Cham.

[22]. Pasyeka N. M. end Pasyeka M. S. Construction of multidimensional data warehouse for processing students' knowledge evaluation in universities. *13-th International scientific and technical conference*, 23-26 February 2016, Lviv, pp. 822–824.

[23] Dronyuk I., Nazarkevych M., Fedevych O. (2016) Synthesis of Noise-Like Signal Based on Ateb-Functions. In: Vishnevsky V., Kozyrev D. (eds) *Distributed Computer and Communication Networks. DCCN 2015. Communications in Computer and Information Science*, vol 601. Springer, Cham https://doi.org/10.1007/978-3-319-30843-2_14

[24] M. Pasyeka, V. Sheketa, N. Pasieka, S. Chupakhina and I. Dronyuk, "System Analysis of Caching Requests on Network Computing Nodes," *2019 3rd International Conference on Advanced Information and Communications Technologies (AICT)*, Lviv, Ukraine, 2019, pp. 216-222, doi: 10.1109/AIACT.2019.8847909.

[25] M. O. Medykovskyy, M. S. Pasyeka, N. M. Pasyeka and O. B. Turchyn, "Scientific research of life cycle perfomance of information technology," *12th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT)*, Lviv, 2017, pp. 425-428, doi: 10.1109/STC-CSIT.2017.8098821.

[26] M. Pasyeka, T. Sviridova and I. R. Kozak, "Mathematical model of adaptive knowledge testing," *5th International Conference on Perspective Technologies and Methods in MEMS Design*, Zakarpattya, 2009, pp. 96-97.

[27] W. Yang, L. Lei and J. Deng, "Optimization and improvement for multi-UAV cooperative reconnaissance mission planning problem," 2014 *11th International Computer Conference on Wavelet Activ Media Technology and Information Processing(ICCWAMTIP)*, Chengdu, 2014, pp. 10-15, doi: 10.1109/ICCWAMTIP.2014.7073351.

[28] Y.-F. Zhang, H.-Y. Duan, and Z.-L. Geng, "Evolutionary mechanism of frangibility in social consensus system based on negative emotions spread," *Complexity, vol. 2017*, Article ID 4037049, 8 pages, 2017.

[29] E. Awad, M. W. Caminada, G. Pigozzi, M. Podlaszewski, and I. Rahwan, "Pareto optimality and strategy-proofness in group argument evaluation," *Journal of Logic and Computation*, vol. 27, no. 8, pp. 2581–2609, 2017.

[30] M. J. Rider, L. A. Gallego, R. Romero and A. V. Garcia, "Heuristic Algorithm to Solve the Short Term Transmission Network Expansion Planning," 2007 *IEEE Power Engineering Society General Meeting*, Tampa, FL, 2007, pp. 1-7, doi: 10.1109/PES.2007.385441.

[31] Liu Lifen, Shi Ruoxin, Li Shuandao and Wu Jiang, "Path planning for UAVS based on improved artificial potential field method through changing the repulsive potential function," 2016 IEEE Chinese Guidance, Navigation and Control Conference (CGNCC), Nanjing, 2016, pp. 2011-2015, doi: 10.1109/CGNCC.2016.7829099.

[32] D. A. R. Wulandari, F. N. Arifin and G. D. Santika, "Implementation North West Corner and Stepping Stone Methods for Solving Logistical Distribution Problem in Tape Production," 2018 2nd East Indonesia Conference on Computer and Information Technology (EIConCIT), Makassar, Indonesia, 2018, pp. 133-138, doi: 10.1109/EIConCIT.2018.8878536.