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DEVELOPMENT OF EQUIPMENT FOR THE FORMALIZATION OF THE PROCESS OF SELECTING INFORMATION FEATURES FOR DISPLAYING INFORMATION ABOUT THE AIR SITUATION

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Abstract. *The work developed a formalized knowledge model for determining signs of violation of airspace use rules. The situations that arise in the airspace are analyzed and the choice of the knowledge representation model is substantiated. The study was conducted using the developed structure of target instructions and an artificial neural network.*
Keywords: *decision support system, knowledge formalization, knowledge model, air traffic, hybrid knowledge model.*

I. INTRODUCTION

The work is devoted to the development of a formalization apparatus for solving the task of selecting information features, which is a necessary component in the construction of information models (IM), which are an element of the information support system (ISS) for assessing the actions of the air adversary (AAA) at control points (CP) of the Air Force (AF).

The task of selecting information features (IF) is inextricably linked to solving the task of recognizing operational-tactical situations (OTS). As a result, the question of formalizing the recognition procedure arises.

II. LITERATURE ANALYSIS

The results of the analysis of modern research in the field of automation of air traffic control show that great attention is paid to the issue of improving of the Information Support System(ISS) of the human operator. However, the problems of formalization of knowledge about the processes of recognition of situational situations (SS) have not yet been finally resolved. This primarily concerns the problem of adequate person, who making the decision (PMD) assessment of the general situation, which is in the area of responsibility of the control body of the automated air traffic control systems (AA TCS), as well as its components - air, meteorological, obstacle, ornithological and other types of situation.

2.1. Subsection title

Only that, the problem regarding the mechanism of safe detection of situational situations, which in the dynamics of development can lead to aviation events and disasters, under the condition of inefficient response of PMD to them, has not been finally resolved.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The main goal of recognition is the construction of effective computational models and methods of formalized descriptions of situations for assigning them to the appropriate classes with the help of information signs and procedures of logical deduction.

IV. RESULTS

1 Analysis of the sources of receiving information about the Air condition

The task of selecting information features for displaying information about the air situation is inextricably linked to solving the task of automating the decision-making procedure, regarding the recognition of situations that may arise in the air space. For this, it is necessary to formalize the process of determining the signs of violation of the rules for the use of airspace (SVRUA).

In order to formalize the process of determining the features of the SVRUA, it is necessary to analyze the system of collecting and processing information about software.

The main source of information about the air enemy is radio engineering troops (RET). Radio engineering troops are designed to conduct reconnaissance of airborne targets and issue information about the start of an air attack, as well as control flights and overflights of aircraft.

In a general form, the scheme of the software information collection and processing system is shown in Fig. 1.

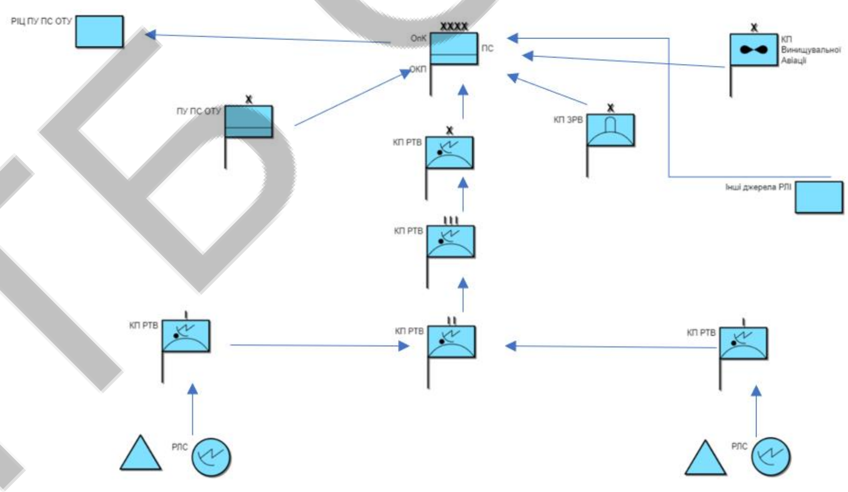


Fig. 1 General diagram of the system for collecting and processing information about the air situation

From the analysis of the given system, it follows that this system has several levels of generalization of information. The main sources of information about software are the control points of radar units (CP RC). At the highest level, the RET units process and generalize information about software received from subordinate units.

The next level of information processing is its processing in the units of units of the radio engineering troops, after which the received information is transferred to the operational and tactical control unit of the Air Force, where automatic and semi-automatic processing of software information takes place with the help of people on the next shift.

After processing the received information about the software in the area of responsibility of the AF OTM, it is displayed on the information display means to ensure decision-making by the relevant persons.

The list of main sources and consumers of information includes the following: radar stations; altimeters; ground radar interrogators; control points of radio technical units and interacting control points of radio technical parts and units of radio technical connections, which are equipped with complexes of automation means (CAM). Other sources of information about the Air Objects (AO) include reconnaissance aircraft, operational command units, units of the AF, border detachments stationed in the area of responsibility of the AF, etc. [4].

When formulating the task of decision-making regarding the identification of the features of the SVRUA in order to formalize it and develop appropriate programs, it is necessary to resolve the fundamental question of the appropriate (for such a system) distribution of functions between a human operator and an electronic computer (computer). For this, an analysis of informational and cognitive approaches to the automation of DMS tasks should be conducted, as well as determine the expediency of using a certain approach when considering this problem area [1].

The setting of decision-making tasks, with the information method, should assume their formalization using a small amount of quantitative initial data and signs. Computers rely on the functions of processing current information about the state of reality, presented in the form of data. All operations that require the use of knowledge about the properties of the environment and systems are performed by a person - the user, who makes decisions.

The informational approach is reflected in the provisions of the theory of rational decisions, which is developed by researchers, mathematicians and economists, it focuses on the use of computational procedures.

That's why, it should be noted that the subject of its study is only the final stage of the decision-making process - the choice of the optimal (best) option and decision, assuming that all preparatory work, which requires the use of knowledge about objective reality, is performed by a person [1].

Cognitive (from Latin cognitio – knowledge, cognition), an approach based on knowledge, it became possible for implementation thanks to the development of AI ideas.

Features of the cognitive approach are that the computer can be assigned functions for formulating or determining the conditions for solving decision-making tasks, as well as finding solutions in unforeseen situations.

As a result of the specified features, the cognitive approach in the development of special mathematical support opens up the possibility of creating such control systems that are distinguished by a high degree of adaptability to the external conditions of the environment, as well as the ability to self-learn.

Human functions in such systems consist in the creation of general mathematical support at the design stage, in the formalization and introduction of expert knowledge into the computer at the stage of setting up the system for a certain subject area. It should be noted that the use of a cognitive approach is absolutely unnecessary for finding solutions to open problems. Such an approach can be implemented in various forms - from systems that provide support for decision-making processes in dialogue mode with the user, to fully automatic systems that manage autonomous activities [4].

2. Development of the apparatus for the formalization of the knowledge model for the determination of signs of violations of the air space use

According to the rules for the use of airspace over the territory of Ukraine, logical-linguistic descriptions of the situations of air traffic within the limits of the responsibility of the MB OTM have been compiled, given in table 1. [2].

Table 1. Typical situations occurring in airspace

№	The name of the situation in the airspace	Description of the situation observed in the air space
1.	Regular (normal) situation	All air traffic objects are carried out in accordance with applications and traffic schedules
2.	The threat of an aerial object crossing the border	The air object is moving in the direction of the state border of Ukraine outside the declaration (without declaration) for flight
3.	Crossing the border by an aerial object	The air object crosses the state border of Ukraine with external ones, outside the declaration (without declaration) for the flight.
4.	Force majeure situation	The air object crosses the state border of Ukraine from the external, outside the declaration (without declaration) for a flight in connection with a force majeure situation.
5.	Hijacking of an aircraft (HA)	The aircraft moves in the direction of the state border from the territory of Ukraine without a declaration (without a declaration) for flight
6.	Violation of airspace use rules (VRUA)	The aircraft is moving in accordance with the flight application in violation of the rules for the use of airspace

They have the following description:

a) if the air object moves according to the application (schedule) for the flight in compliance with the established procedure and rules for the use of air space, then this situation is characterized as standard (S_o);

b) if the air object moves without an application (outside the schedule) for flight or violates the established procedure (rules) for the use of airspace, then this situation is characterized as irregular (S_1);

c) if the air object of another state moves without a request (out of schedule), and its current coordinates belong to the Z_P reconnaissance zone, and the extrapolated coordinates belong to the zone Z_T, then this situation can be characterized as a threat of crossing the state border $(S_{1.1})$;

d) if the air object of another state moves without an application (out of schedule), and its current coordinates belong to the zone Z_T, and the previous coordinates belonged to the zone Z_{Π}, then this situation can be characterized as crossing the state border $(S_{1.2})$;

e) if the air object of another state moves from the outside in the direction of the state border and a force majeure situation occurs on board it, then the situation can be characterized as force majeure $(S_{1.3})$;

f) if the air object moves according to the application (schedule) for the flight, but in violation of the procedure (rules) for the use of air space, then this situation can be characterized as a violation of the flight regime $(S_{1.4})$;

g) if there is information about the hijacking of an aerial object or it is moving in the direction of the state border, does not follow commands and its spatial coordinates belong, then this situation can be characterized as hijacking $(S_{1.5})$ [3].

The decision-making process in the management of complex objects and systems is inextricably linked to solving the task of recognizing situations. But the high complexity of recognition tasks does not allow us to consider the issue of their formalization as completely resolved.

The formalization of the process of determining the signs of SVRUA requires the selection of the knowledge representation model shown in Fig. 2 [2].

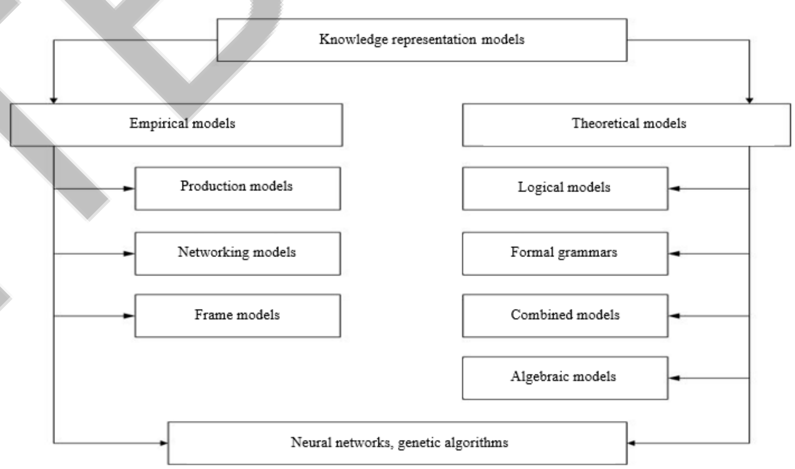


Fig. 2 Knowledge representation models

Because when building OT classes, one should take into account the fact that the number of ISes characterizing situations in the air space can be practically unlimited. A number of requirements must be made to the ISS: the set of ISSes must be necessary and, at the same time, sufficient to describe the situations in the process of assessing the situation at the CP and allow the most complete presentation of the model of the problem area in the computer memory.

For the formalization of such tasks, it is appropriate to use network and logical models of knowledge. In particular, we are talking about the use of combined models based on the use of the structure of target instructions (STI) and the calculation of first-order predicates [4].

The main elements of this formalization apparatus are purpose and relation. The goal is the state of the subject area, which is characterized by: a set of states of objects of physical reality; a multitude of events; transition rules; actions that must be performed for the object to achieve a certain state [3].

However, STI has a number of disadvantages: the process of knowledge formalization is complicated; difficult implementation of the procedure for checking the consistency of the formalized description of software knowledge; the procedure for verifying the completeness of the formalized description; v-value of the pragmatic interpretation for each of the vertices of the STI; a non-formalized procedure for processing semantic (qualitative) information, which is used by experts, and replacing it with indicative (quantitative) information, which is used by the STI.

The formal apparatus of the number of predicates, which is used along with the STI [1], is practically devoid of the mentioned shortcomings.

At the same time, the model of knowledge, based on the calculation of first-order predicates, has the following advantages and disadvantages.

Advantages: ease of creation and understanding of separate product rules, ease of addition and modification of rules, simplicity of the mechanism of logical conclusion.

Disadvantages: vague clarity of the mutual relations of the rules, the difficulty of evaluating a holistic image of knowledge, low processing efficiency; lack of flexibility in logical conclusion.

However, to solve this problem, the possibility of using artificial neural networks (ANN) should be taken into account. ANNs are used to solve a fairly wide range of tasks, namely when solving problems of pattern recognition, both static and dynamic, as well as when analyzing incomplete and contradictory data. The main disadvantage of ANNs is limited opportunities for obtaining explanations about the process of making decisions.

For the process of determining the signs of SVRUA, it is necessary to analyze the totality of IO. These data can be divided into two groups:

– radar reconnaissance data: planar coordinates of AO at this moment in time (X_j^n, Y_j^n); AI flight height (H_j^n); speed of movement of AO (V_j^n); course of motion of AO (ψ_j^n); flight time (t_j^n); real flight application number (N_{3j}); the number of air objects that are actually in the air (Kj); presence or absence of a distress signal (Rj); sign of state affiliation (ДП); presence or absence of adverse weather conditions (Mj); the presence or absence of unfavorable ornithological conditions (Orj).

–dispatch control data: given height echelon ($\Delta H_з$); set flight speed ($\Delta V_з$); set flight course ($\Delta \psi_з$); the specified time interval of the flight of the air object over the corresponding points ($\Delta t_з$); planned flight application number (N зпл); the number of air objects specified in the flight application (Nз).

It is also necessary to take into account the location of the software in a certain area of responsibility of the MB OTM. Known spatial characteristics are used to divide the limits of responsibility of the Air Force into areas of air space: the radar field, the direction of alerting of duty forces, the limits of responsibility of the Air Force, as well as the flight corridors of the air object. Areas of responsibility of MB OTM are schematically depicted in Fig. 3.

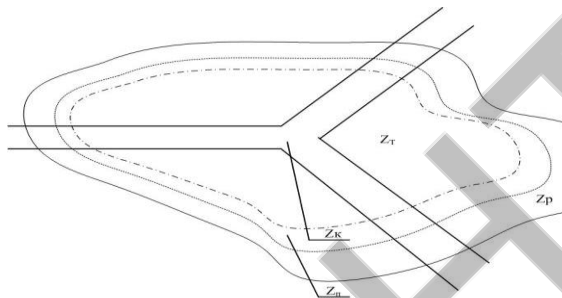


Fig. 3 Spatial representation of the boundary of responsibility of MB OTM

Each zone has certain characteristics: coordinates, area, etc. [2].

If the zone of responsibility is denoted by Zo, then the ratio describing its component parts (Fig. 3) can be represented by the following expression:

$$\{Z_P, Z_T, Z_\Pi, Z_K\} \subset Z_O \tag{2.1}$$

Areas of responsibility of MB OTM are divided into: the airspace zone, which includes the flight corridors of the AO (Zk); the airspace zone directly above the territory of the MB (Z_T); the external border zone, which characterizes the bringing of regular forces of the MB to readiness No. 1 (Zп); reconnaissance zone of the windy space outside the territorial boundary of responsibility of the MB and zone Zп (Zp).

The regular (S_0) and non-regular (S_1) situation can be presented in the form of a formalized description:

$$\begin{aligned}&(\{X_i, Y_i\} \in Z_k) \cap (V_j \in \Delta V_з) \cap (H_j \in \Delta H_j) \cap (\Psi j \in \Delta \Psi j) \cap (t_j \in \Delta t_з) \cap \\ &\cap (N_{зj} = N_{зпл}) \cap (K_j = K_з) \cap (\mathrm{R}_j = 0) \Rightarrow S_0,\end{aligned} \tag{2.2}$$

$$\begin{aligned}&(\{X_i, Y_i\} \notin Z_k) \cap (V_j \notin \Delta V_з) \cap (H_j \notin \Delta H_j) \cap (\Psi j \notin \Delta \Psi j) \cap (t_j \notin \Delta t_з) \cap \\ &\cap (N_{зj} \neq N_{зпл}) \cap (K_j \neq K_з) \cap (\mathrm{R}_j = 1) \Rightarrow S_1.\end{aligned} \tag{2.3}$$

$$\begin{aligned}&(\{X_i, Y_i\} \notin Z_k) \cap (V_j \notin \Delta V_з) \cap (H_j \notin \Delta H_j) \cap (\Psi j \notin \Delta \Psi j) \cap (t_j \notin \Delta t_з) \cap \\ &\cap (N_{зj} \neq N_{зпл}) \cap (K_j \neq K_з) \cap (\mathrm{R}_j = 1) \Rightarrow S_1.\end{aligned} \tag{2.4}$$

The threat of crossing the state border:

$$(\{X_i, Y_i\} \in Z_p) \cap (N_{зj} \neq N_{зпл}) \cap (\{X_i^{є}, Y_i^{є}\} \in Z_T) \cap (ДП_j = 0) \Rightarrow S_{1.1} \tag{2.5}$$

Crossing the state border:

$$\left(\{X_i,Y_i\}\in Z_T\right)\cap\left(N_{\text{з}j}\neq N_{\text{зпл}}\right)\cap\left(\{X'_i,Y'_i\}\in Z_П\right)\cap\left(\text{ДП}_{\text{j}}=0\right)\Rightarrow S_{1.2} \quad (2.6)$$

Force majeure situation:

$$\left(\{X_i,Y_i\}\in Z_p\right)\cap\left(N_{\text{з}j}\neq N_{\text{зпл}}\right)\cap\left(\{X^{є}_i,Y^{є}_i\}\in Z_П\right)\cap\left(\text{R}_{\text{j}}=1\right)\cap\left(\text{ДП}_{\text{j}}=0\right)\cap$$
$$\cap\left(M=1\right)\cap\left(Or=1\right)\Rightarrow S_{1.3}. \quad (2.7)$$

Flight mode violation:

$$\left(\{X_i,Y_i\}\notin Z_k\right)\cap\left(V_j\notin\Delta V_{з}\right)\cap\left(H_j\notin\Delta H_j\right)\cap\left(\Psi j\notin\Delta\Psi j\right)\cap\left(t_j\notin\Delta t_{з}\right)\cap$$
$$\cap\left(N_{\text{з}j}=N_{\text{зпл}}\right)\cap\left(K_j\neq K_{з}\right)\cap\left(\text{R}_{\text{j}}=0\right)\Rightarrow S_{1.4}. \quad (2.8)$$

Aircraft hijacking:

$$\left(\{X_i,Y_i\}\in Z_T\right)\cap\left(\{X^{є}_i,Y^{є}_i\}\in Z_P\right)\cap\left(\{X^{є}_i,Y^{є}_i\}\in Z_П\right)\cap\left(\text{В}К=0\right)\Rightarrow S_{1.5}. \quad (2.9)$$

Analysis of the descriptions given in subsection 2.1 allows to reveal the relationship between disparate current data, the combination of which makes it possible to detect abnormal situations in the airspace.

The following ratios can be found from the description of the staffing situation:

A) relation of belonging ($\in$):

– current plane coordinates of the AO(X_i,Y_i) to the flight corridors (Z_K), which is determined by the ratio:

$$(X_i,Y_i)\in Z_k, \quad (2.9)$$

– AO flight height (H_j) to the given height echelon (ΔH_j), which is determined by the ratio:

$$(H_j\in\Delta H_j), \quad (2.10)$$

– the speed of movement of AO (V_j) of the given flight speed $(\Delta V_{з})$, which is determined by the ratio:

$$(V_j\in\Delta V_{з}), \quad (2.11)$$

– the course of movement of AO (Ψj) according to the given flight course $(\Delta\Psi j)$, which is determined by the ratio:

$$(\Psi j\in\Delta\Psi j) \quad (2.12)$$

– compliance of the flight time (t_j) of the given points with the given time interval $(\Delta t_{з})$, which is determined by the ratio:

$$(t_j\in\Delta t_{з}) \quad (2.13)$$

B) similarity ratio (=):

– number of the application (schedule) for the actual$(N_{\text{з}j})$ and scheduled$(N_{\text{зпл}})$ flight, which is determined by the ratio:

$$(N_{\text{з}j}=N_{\text{зпл}}) \quad (2.14)$$

– the number of AOs (K_j) that are actually in the air and specified in the flight application $(K_з)$, which is determined by the ratio:

$$(K_j = K_з) \tag{2.15}$$

C) ratio of presence (absence):
– absence of signs of distress on board the aircraft, which is determined by the ratio:

$$(\mathrm{R_j} = 0) \tag{2.16}$$

If at least one relationship from the description of the regular situation is not fulfilled, then such a situation characterizes any non-regular situation.

The following ratios can be found from the description of the abnormal situation:

A) relation of belonging (∈):

– current planar coordinates of AO (X_i, Y_i), to the zone Z_p, which is determined by the ratio:

$$(X_i, Y_i \in Z_p) \tag{2.17}$$

– extrapolated planar coordinates of AO (X_i^e, Y_i^e), to the zone (Z_T), which is determined by the ratio:

$$(\{X_i^e, Y_i^e\} \in Z_T) \tag{2.18}$$

B) similarity ratio (=):

– state ownership of AO is "foreign", which is determined by the ratio:

$$(\mathrm{ДП_j} = 0) \tag{2.19}$$

C) ratio of presence (absence):

– absence of signs of distress on board the aircraft, which is determined by the ratio (2.16).

From the description of the state border crossing situation, the following relationships can be identified:

A) relation of belonging (∈):

– current planar coordinates of AO (X_i, Y_i), to the zone Z_T, which is determined by the ratio:

$$(X_i, Y_i \in Z_T) \tag{2.20}$$

– of the previous planar coordinates of the AO $(X_i^`, Y_i^`)$ to the zone $(Z_П)$, which is determined by the ratio:

$$(\{X_i^`, Y_i^`\} \in Z_П) \tag{2.21}$$

B) similarity ratio (=):

– state ownership of software is "foreign", which is determined by the ratio (2.19)

C) ratio of presence (absence):

– absence of signs of distress on board the aircraft, which is determined by the ratio (2.16).

From the description of the situation characterized as force majeure, the following relationships can be identified:

– extrapolated planar coordinates AO $\left(X_i^e, Y_i^e\right)$ to the zone $\left(Z_{\Pi}\right)$, which is determined by the ratio:

$$\left(\left\{X_i^e, Y_i^e\right\} \in Z_{\Pi}\right) \tag{2.22}$$

– current planar coordinates of AO $\left(X_i, Y_i\right)$, to the zone Z_P, which is determined by relation (2.17).

A) similarity ratio (=):

– state ownership of AO is "foreign", which is determined by the ratio (2.19)

B) ratio of presence (absence):

– the absence of adverse weather conditions is determined by the ratio:

$$\left(M = 0\right) \tag{2.23}$$

– the absence of an unfavorable ornithological situation is determined by the ratio:

$$\left(Or = 0\right) \tag{2.24}$$

– the presence of signs of distress on board the aircraft, which is determined by the ratio:

$$\left(\mathrm{R_j} = 1\right) \tag{2.25}$$

From the description of the situation that determines the violation of the flight regime, the following ratios can be identified:

A) relation of belonging ($\in$):

– current planar coordinates of the AO $\left(X_i, Y_i\right)$ to the flight corridors (Z_K), which is determined by the ratio (2.9);

– AO flight height (H_j) to the specified height echelon $\left(\Delta H_j\right)$, which is determined by the ratio (2.10);

– the speed of movement $\left(V_j\right)$ of the given flight speed $\left(\Delta V_з\right)$, which is determined by the ratio (2.11);

– the course of movement $\left(\Psi j\right)$ according to the given flight course $\left(\Delta \Psi j\right)$, which is determined by the ratio (2.12);

– compliance of the flight time $\left(t_j\right)$ of the given points with the given time interval $\left(\Delta t_з\right)$, which is determined by the ratio (2.13);

B) similarity ratio (=):

– number of the application (schedule) for the actual $\left(N_{зj}\right)$ and scheduled $\left(N_{зпл}\right)$ flight, which is determined by the ratio (2.14);

– the number of AOs $\left(K_j\right)$ that are actually in the air and specified in the flight application $\left(K_з\right)$, which is determined by the ratio (2.15);

C) ratio of presence (absence):

– absence of signs of distress on board the aircraft, which is determined by the ratio (2.16).

From the description of the situation that defines the Air Force, the following ratios can be identified:

A) relation of belonging ($\in$):

– current planar coordinates of AO (X_i, Y_i), to the zone Z_T, which is determined by relation (2.20);

– extrapolated planar coordinates AO (X_i^e, Y_i^e), to the zone (Z_Π), which is determined by the ratio (2.22);

– of the extrapolated planar coordinates AO (X_i^e, Y_i^e), to the zone (Z_P), which is determined by the relation (2.18):

$$\left(\{X_i^e, Y_i^e\} \in Z_P\right) \tag{2.26}$$

B) similarity ratio (=):

– state ownership of AO is "own", which is determined by the ratio:

$$\left(\text{ДП}_\text{j} = 1\right), \tag{2.27}$$

C) ratio of presence (absence):

– absence of signs of distress on board the aircraft, which is determined by the ratio (2.16);

– non-fulfillment of commands transmitted on board the aircraft is described by the ratio:

$$\left(BK = 0\right), \tag{2.28}$$

Based on the above ratios, it is possible to draw up a structure of target instructions for determining the signs of violation of the air use rules (Addition B.1).

It can be seen from the figure that the use of initial conditions necessitates the development of means for inputting initial data.

The main markings in Fig. 4 are:

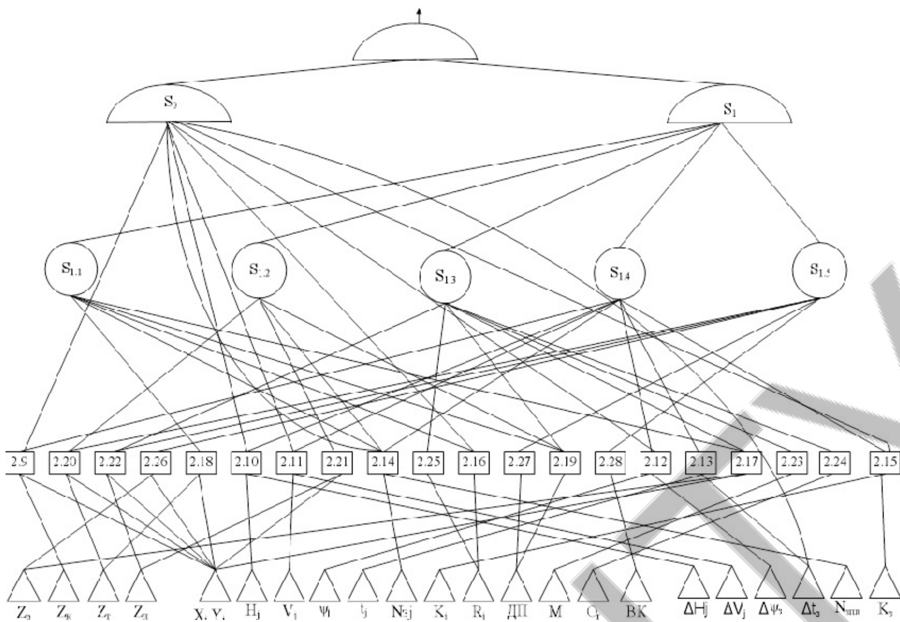
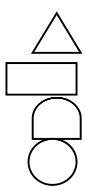


Fig. 4 Example of the structure of target instructions for recognition of situations in airspace



– initial conditions;

– vertices of comparison;

– vertices of the OR type;

– top of type I

Vertices AND and OR are used to implement logical generalizations of comparison results.

In order to assess the quality of solving the situation recognition task, an experiment should be conducted, for which the developed functional network and artificial neural network should be used.

Depending on the adopted method of describing a priori data, different recognition algorithms can be built. Most often, the mathematical apparatus of fuzzy sets is used to describe a priori summaries. The formalized description of quantitative features is represented by the function of belonging to the value of the features in the form of a fuzzy LR-interval. An example of such a representation is given in Fig. 5

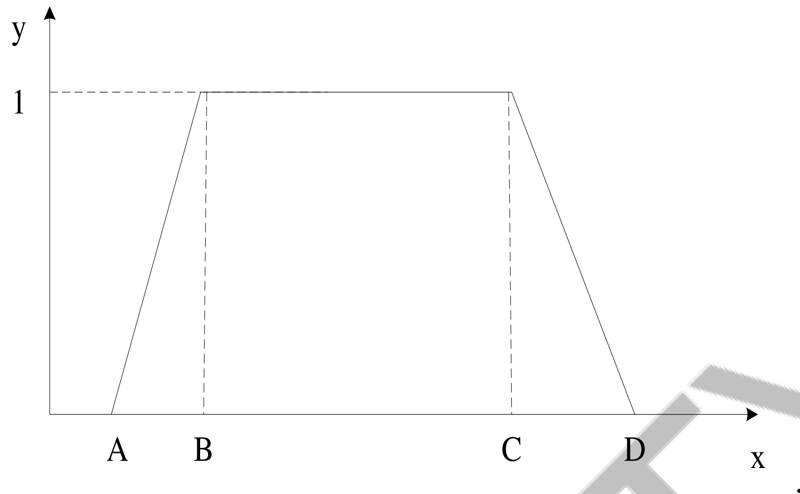


Fig. 5 Distribution function of possible parameter values

In Fig. 5, values B and C represent the lower and upper limits of the most likely values of the characteristic, and A and D are the minimum and maximum values of the characteristic.

The description of feature values using LR-intervals has the following advantages: the possibility of presenting features with stochastic and non-stochastic uncertainty; ease of description from the user's point of view; high expressiveness in terms of descriptive possibilities; ease of subsequent use when creating software modules.

Numerical values of quantities A, B, C and D are quite often determined on the assumption that the characteristic value has a normal distribution law. At the same time, the assumed parameters of the fuzzy LR-interval can be determined assuming that points B and C are two standard deviations from the mean value of parameter x, and points A and D are three standard deviations away. The coordinates of the areas of responsibility of MB OTM are presented in the form of RL-intervals presented in table 4.

Table 4. Coordinates of the area of responsibility of the MB OTM are presented using RL-intervals.

Flight zones	LL	LR	RL	RR
Zk X	6000	6500	6700	7200
Zk Y	1000	4500	4700	5200
Zт X	7200	8000	9000	9200
Zт Y	5200	6000	7000	7200
Zп X	9200	10000	11000	12000
Zп Y	7200	8000	9000	10000
Zр X	12000	13000	14000	16000
Zр Y	10000	11000	12000	14000

After determining the features of some object (situation), it is necessary to assign the observed object to some class of situations based on available a priori data and a posteriori summaries.

Making a decision about the situation in the airspace for each functional network (FN_{1-6}) is carried out using the following operations:

$$\Phi M_1 = \prod_{i=1}^{n} \overline{D}j + \prod_{i=1}^{n} \overline{Fj}, \tag{2.29}$$

$$\Phi M_2 = \sum_{i=1}^{n} \overline{D}j \cdot \sum_{i=1}^{n} \overline{Fj}, \tag{2.30}$$

$$\Phi M_3 = \max(\min(x_i y_i)), \tag{2.31}$$

$$\Phi M_4 = \frac{\sum_{i=1}^{n} \overline{D}j\overline{Fj}}{N}, \tag{2.32}$$

$$\Phi M_5 = \min(\max(x_i y_i)), \tag{2.33}$$

$$\Phi M_6 = \frac{\sum_{i=1}^{n}(\overline{D}j\overline{Fj}) - \prod_{i=1}^{n}(\overline{D}j\overline{Fj})}{1 + \sum_{i=1}^{n}(\overline{D}j\overline{Fj}) - 2 \cdot \prod_{i=1}^{n}(\overline{D}j\overline{Fj})} \tag{2.34}$$

Taking into account the above data, it is possible to carry out testing to evaluate functional networks in view of the number of correctly defined situations. A diagram was constructed that shows the effectiveness of FN_{1-6} in solving the task of recognizing situations (Fig. 6).

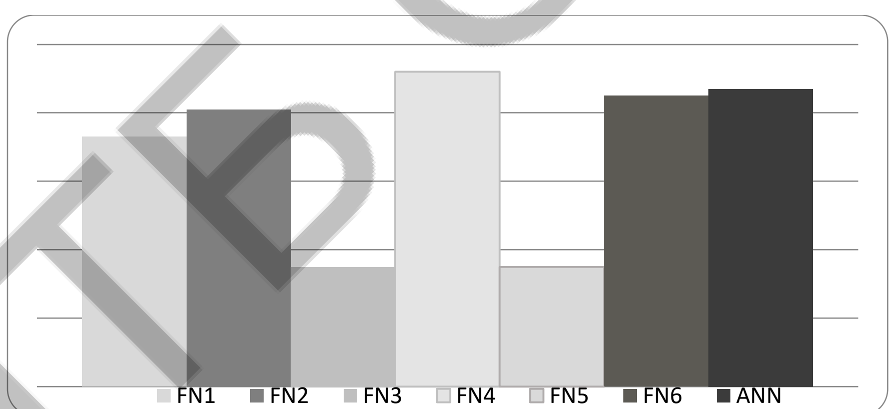


Fig. 6 Results of the functional network and artificial neural network recognition algorithm

We will analyze functional networks. Let's set a threshold value equal to 0.5. FN_3 and FN_5 have a too low coefficient of correct identification of situations, that is, they are not effective. This is due to the logical rules used in FN data. If at least one value equals 0, the other values are not taken into account.

The functional network developed in this way is able to correctly recognize 37-90% of situations.

However, as mentioned above, ANN is widely used to solve the problem of situation recognition.

The MATLAB simulation package was used to solve the problem of situation recognition using ANN.

ANN is a multi-layer forward propagation perceptron without feedback. This type of ANN is quite often used to solve the tasks of recognition, classification and management [4]. The created ANN was trained by the method of backpropagation of errors [2].

A training sample was formed to adjust the parameters of the ANN for the solution of the situation recognition task. The training sample was drawn in such a way as to reflect the main characteristics of the situations. The training of the network was carried out using those data that clearly identified this or that situation.

After filling the database with examples from the test sample, each recognition system was tested and the probability of correct recognition was determined for each method.

The results of the experiment revealed that the probability of correctly recognizing the situation in the airspace when using ANN was 88%.

V. CONCLUSIONS

In this work, a data formalization apparatus was developed and a knowledge formalization model was developed in the form of a structure of target instructions for a formalized description of the process of solving the task of recognizing situations that may arise in the airspace in the area of responsibility of the MB OTM. An experiment was conducted using the developed structure of target instructions and an artificial neural network. It is more appropriate to use a trained ANN to solve the task.

Solving the task of selecting information features is a necessary component in the construction of information models. Defining the list of information features that will ensure the decision-making process and justifying the composition of information elements is the main component in creating an information model to support decision-making. Therefore, the work has developed a procedure for selecting information features that are necessary and sufficient for solving the tasks of recognizing situations in the airspace and evaluating the actions of the air adversary.

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