RISK ASSESSMENT OF OFFENCES AT STATE BORDER USING FUZZY HIERARCHICAL INFERENCE

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A model of fuzzy inference to risk assessment of offenses in control. The useage of models provides an opportunity: the use of quality indicators, taking into account inaccurate, approximate information, using knowledge of experts, which are given in the form of fuzzy rules. The complexity of constructing fuzzy model conclusion is solved by a hierarchical system of opinion and knowledge bases.

Topicality. One of the improvements in management of departments and agencies of the State Border (SB) is to increase the speed and quality [1]. Range of tasks in such an environment significantly increases, most of them are weakly-formalized and unformalized nature, the conditions of their solution is continuously deteriorating. The need for new methods of management bodies of control SB are evident during profiling (assessment) risk [2]. The most critical issue is risk assessment of offenses relative in control on SB.

Formulation of the problem. Performances of the mathematical problem of risk assessment as a feasible nonlinear object with the set of input variables $X=\{x_i\}$ and one output variable y:

$$y=f_y(x_1, x_2,\dots, x_n) \ . \qquad (1)$$

How to choose the signs of input variables (risk indicators) offense in control. Output variable y is an indicator of the degree of possible violations of security control on SB.

To automate the risk assessment at the State Border Guard Service of Ukraine (SBGSU) is established subsystem "RISK" [3]. Analysis of its application shows that worked through the issue of automation of storage and delivery on request relevant information. Question analysis (processing) of this information remains the prerogative of the SBGSU personnel on the basis of his experience, intuition, subjective perceptions. Schengen information system (Schengen Information System - SIS) is designed to provide common external borders and integration into a single system, necessary for the Schengen Convention [4]. SIS contains data on individuals, yaks crossed the common border of the European Union (EU), illegal immigrants, lost and false travel documents, persons missing more. Risk assessment of involvement with offenders is not made.

That is, the existing information and telecommunication systems SBGSU and the EU is unable to make sufficient timely and quality support decisions on risk and need further improvement.

Analysis of recent research and publications. For risk assessment should be applied not only qualitative judgments about these risks, but also various methods of quantitative analysis.

In [5] presented research aimed at automating the distribution of capabilities in the protection of control on SB based on optimization methods. However, the tasks of risk assessment is given insufficient attention. In [6] proposed a model that is based on a binary interpretation of signs (risk indicators) describing the site. Analysis of this model showed that this interpretation is not suitable for assessing the majority of risk indicators that are qualitative in nature.

In other subject areas for risk assessment is most often used device of probability theory and mathematical statistics [7, 8]. However, given that decisions on the basis of risk assessment areas, occurs in an environment where: events do not occur with enough frequency, most signs are good quality and presented in natural-language descriptions, and their rating is based on vague opinions and estimates of experts, information the main parameters are incomplete and unclear, etc. - use probabilistic methods is impossible.

One of the promising areas of modern high-tech simulation is unclear, due to increasing trend of complexity and formal mathematical models of real systems and management processes associated with the desire to improve their adequacy and to consider a set of different factors that influence decision-making processes.

The question of risk of crossing the state border with the use of fuzzy inference models considered in [9], based on 3-5 features describing the object of research. The study of more complex models of risk assessment of offenses with a lot of signs according to the method [10] (see Table 1) is carried out.

Table 1. The tasks of analysis and risk assessment of offenses in SB

№ i/o	Name of task	Signs of description (entrances variables)		Risk estimation	Leading actions
1	Estimation of risk of offence on SB	x_1 - is **a volume:** the volume of display of offence, which causes a disturbance, is estimated		Degree of possibility of realization of offence	Adjustment problems of border dresses, Border Guard officers and border control
		How the offense with other factors – y_1	x_2 - **implementation:** the level of reacting of organization is estimated on offence		
			x_3 - is **tendencies:** it is estimated, degree of disturbance by the tendency of change of display of offence		
		The level of concern about the offense – y_2	x_4 - is **a seriousness:** the level of disturbance of organization is estimated in relation to the display of offence		
			x_5 - is **priority:** the level of disturbance of government is estimated in relation to the display of offence		
			x_6 - is **the disturbance of society:** the level of disturbance of public is estimated in relation to the display of offence		
		How the offense with other factors – y_3	x_7 - is **a generator:** the level of disturbance of influencing of offence is estimated on other offences		
			x_7 - - **STEPPYUEH:** the level of disturbance of external factors which influence on activity of service is estimated.		

The purpose of the article - a methodological study using the apparatus of fuzzy logic and presentation of the analysis automation tools for incoming data on violations of control.

The content. The authors suggest the use of fuzzy inference model for evaluation of crime control, according to the mathematical formulation of problem (1). Fuzzy logical conclusion - this approximation of "inputs-outputs" depends on the basis of linguistic expression <IF- THEN>. For example, drug smuggling, has a high volume, trends and have a high level, the degree of possibility of its occurrence in SB is high.

Structure of the fuzzy conclusion includes the following modules [12]:

fuzzy factor that converts a fixed vector of input variables (factors affecting) (*X*) in the vector of fuzzy sets that are needed for fuzzy inference;

fuzzy knowledge base, consisting of: base rules, which contains information about the dependence $Y=f(X)$ in the form of linguistic rules <IF-THEN> and intended for formal presentation of empirical knowledge, or knowledge of experts in a subject area, a database that contains parameters of membership functions and the coefficients of the importance of rules;

membership function that is used to represent linguistic terms as fuzzy sets;

fuzzy inference machine, which is rules-based knowledge base determines the value of output variable in a set $\widetilde{Y}$ of corresponding fuzzy values of input variables ($\widetilde{X}$);

defazzyfikator that converts output fuzzy sets in a clear number Y.

Content interpretation of fuzzy model involves the selection and specification of input and output variables of the fuzzy system output. Each sign, see. Table. Formalized as a level of compliance with offenses. For example, the volume: measured by the fact whether the offense generates concern - x_1: Obviously, the higher the score, the more can be carried out illegal activity.

In our case, 8 input variables. To clarify the model in the future may apply additional indicators.

Output variable is the level of the degree of possibility of offense - D: transportation of contraband, weapons, drugs, etc. on a specific area (checkpoint control on SB).

In the fuzzy model of risk of illegal activity all variables are presented as linguistic, universal set of which $U=\{u_1, u_2,\ldots, u_n\}$ is measured in points in the interval of real numbers from 1 to 5 staff based on their knowledge and experience.

As a term-set of variables we will use the set L_1 = {"low", "medium", "high" level}.

Building a membership function terms "low", "medium", "high" that are used for evaluation of linguistic variables may be achieved through the method of statistical processing of expert information that is presented in [12].

The next step - building a fuzzy knowledge base. Description of the problem areas of risk control requires a large number of rules (see Table 1). When a large number of parameters of the construction of expression "input-output" becomes quite complicated. This is because in the memory of man also held up to 7 ± 2 concepts of tag [11]. In complex systems, a condition which is characterized by many features, there is a problem of completeness of knowledge base. It is known that the number of rules needed to describe the n input variables whose values are determined using m terms, equal to $R=m^n$ [12]. For example, in our case, n = 8, m = 3, then the number of rules R = 83 = 512.

Thus, the number of rules increases exponentially with increasing number of input variables, resulting in increased time and complexity of the output logical decision. Knowledge base containing a large number of rules are complex in perception, editing and use. But decision-making process requires, however, full understanding of the particular situation. This contradiction is solved by constructing a hierarchical knowledge base [13]. This approach corresponds to the hierarchical structure of the SBGSU process in special situations. In this regard, to hold the hierarchical classification of the parameters on it and build a tree report that will determine the system of nested into each other expression-knowledge of lower dimension. An example of such a tree to 8 input variables (see Table 1) Shown in Fig. 1. From the example shows that knowledge of the type $D=f_5(x_1,x_2,\ldots,x_8)$ the relationship of inputs x1-x8 with the release of D, replaced by a sequence of relationships: $D=f_5(x_1,y_1,z)$, $y_1 = f_1(x_2,x_3)$, $y_2 = f_2(x_4,x_5,x_6)$, $y_3 = f_3(x_7,x_8)$, $z = f_4(y_2,y_3)$, where y_1,y_2,y_3,z - intermediate linguistic variables.

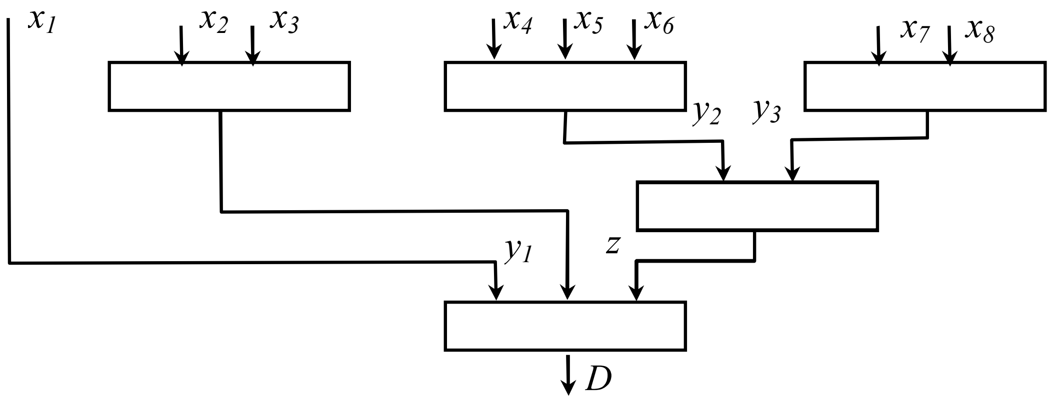


Figure 1. Hierarchical tree report

Thus the number of rules R = 33 +32 +33 +32 +32 = 27 +9 +27 +9 +9 = 81, significantly less compared with the usual conclusion.

Due to the principle of hierarchy can be considered a significant number of parameters that affect the overall assessment. Feasibility porivnevoho representation of expert knowledge is due not only to the natural hierarchy of objects of evaluation, but also the need to take account of additional parameters as the accumulation of knowledge about the object.

Based on the expert survey constructed fuzzy knowledge base of fuzzy systems $D=f_5(x_1,y_1,z)$, $y_1 = f_1(x_2,x_3)$, $y_2 = f_2(x_4,x_5,x_6)$, $y_3 = f_3(x_7,x_8)$, $z = f_4(y_2,y_3)$, which are given in Table. 2.

The method of activation will be *min*. Since all the rules as a logical connection to pidumov only applies fuzzy conjunction (the operation "AND"). As a method of aggregation will use the *min*-conjunction operation. For accumulation endings rules will use the *max*-disjunction. As defazzyfikatsiyi method will use the center of gravity method.

Feature of fuzzy inference in the hierarchical knowledge base is the lack of procedures and defazzyfikatsiyi fazzyfikatsiyi for intermediate variables (y_1, y_2, y_3 and z in Fig. 1). The result of inference in a fuzzy set directly transmitted to the machine fuzzy logical deduction the next level of hierarchy. Therefore, to describe the intermediate variables in the hierarchical fuzzy knowledge bases of a set only term-set, no definition of membership functions.

Table 2. Fuzzy Knowledge Bases

Fuzzy knowledge base on $y_1 = f_2(x_2,x_3)$			Fuzzy knowledge base on $y_2 = f_3(x_4,x_5,x_6)$			
Low	Low	Low	Low	Low	Low	Low
Middle	Low	Low	Low	Middle	Middle	Middle
Middle	High	Middle	Middle	High	Middle	Middle
High	Middle	Middle	Middle	Middle	High	Middle
High	High	High	High	High	High	High

Fuzzy knowledge base on $y_3 = f_4(x_7,x_8)$			Fuzzy knowledge base on $z = f_5(y_2,y_3)$		
Middle	Low	Low	Low	Middle	Low
Low	Middle	Middle	Low	Low	Low
Middle	Low	Middle	Middle	Low	Low

Middle	Middle	Middle	Middle	Middle	Middle
Middle	High	High	High	Middle	Middle
High	High	High	High	High	High

Fuzzy knowledge base on $D=f_1(x_1,y_1,z)$			
Low	Middle	Low	Low
Low	Low	Middle	Low
Middle	Middle	Low	Middle
Middle	Middle	Middle	Middle
High	Middle	Middle	Middle
High	Middle	High	High

The implementation model of fuzzy inference by using the package fuzzyTech [14]. It found the original value of variable D, for given input variables:

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	D
5	4	4	3	4	3	1	2	4,2
1	1	2	1	4	3	2	3	3,3

Figure 2. shows the hierarchical scheme of fuzzy inference constructed in the environment fuzzyTech 5.8.

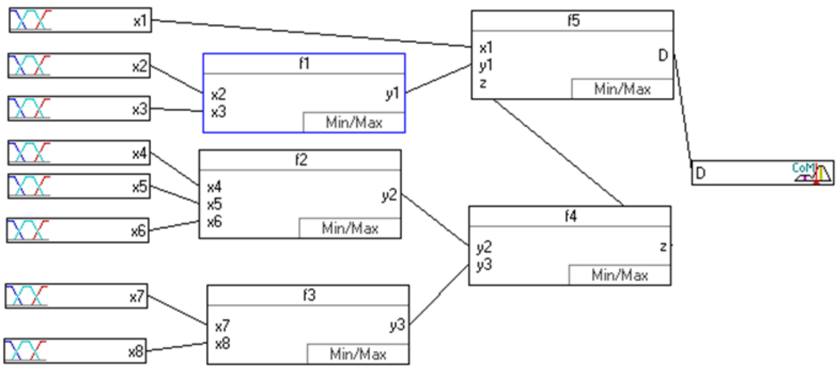


Figure 2. Hierarchical scheme of fuzzy inference

The calculated results coincide with those obtained experimentally.

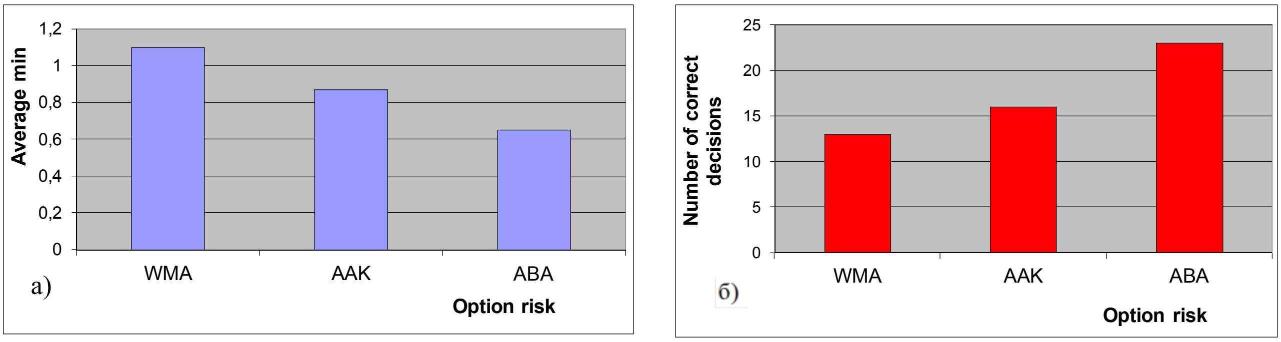
Operationalize the model implemented as a software module "Risk assessment offense", which proposed to include subsystem "RISK".

Check the adequacy of the developed model of fuzzy inference made by the experiment. The experiment was conducted at the department of integrated border management of the National Academy of SBGSU. For the experiment, were selected data on offenses that were used for illegal activity through the control on SB at different times in different parts of the border service.

The experiment involved three study groups: two control and one experimental (20 students in each). During the experiment, each listener provided information about 30 descriptions of possible situations of control, and 15 of each category (high risk and low risk). The task of the inspectors first control group consisted of assess the situation and take it to one of two categories (high and low degree of involvement in illegal activities) without the use of automation. The task of students second control group consisted of assess the situation and take it to one of two categories of application software module based on the model [6].

The task of inspectors experimental group was to assess situations and refer them to one of two categories with the use of automation (software module developed by the author of "Risk assessment offense"). After entering the last parameter is risk assessment in points. If it is within 5.4 points, the situation is evaluated highly the possibility of offense.

The researchers evaluated the following parameters: time spent on assessment of the situation, the quality of decision - evaluation coincides with the existing offenses (correct decision), the assessment does not match (wrong decision). Experimental results, which are shown in Fig. 3.a - on time for assessment of offenses in Figure 3.b - the quality of the decisions indicate that application of the developed software module based on the model of hierarchical fuzzy inference "Risk assessment offense" allows you to: reduce the time to assess the offense, 1,7 times compared with the risk assessment without automation, increase the number of correct solutions in 1,8 times compared with the risk assessment without automation and 1,2 times compared with the known approach.



WMA- without automation; AAK - automation (known approach);
ABA - automation (developed approach)

Figure 3. Results of experimental verification

Conclusions

Thus, the paper presents a model of fuzzy inference of risk offense to control illegal activity and by its experimental verification. Application of this model, unlike the existing offers an opportunity: the use of quality indicators, taking into account inaccurate, approximate information about important features, the usage of knowledge of experts from the Border Guard Service - experts who served in the form of fuzzy rules of inference, a more qualitative assessment of the object under research during profiling risks. The complexity of constructing fuzzy model conclusion is solved by a hierarchical system of opinion and knowledge bases. Implementation of this model within the software and algorithmic provision of information and telecommunications systems will enable SBGSU to reduce time for risk profiling and improve the quality of decisions made.

The proposed approach requires the development of formalization of knowledge and experience, which were accumulated by experts (staff officers, heads of departments (agencies, departments, administration, supervisors), teachers of educational institutions, developers of an integrated information system, "Hart", which is the prospect for further research in this direction.

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