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JUSTIFICATION OF METHOD OF PROCESSING DIFFERENT INTELLIGENCE INFORMATION IN GEOINFORMATION SYSTEMS OF SPECIAL PURPOSE

Geographic information systems are increasingly being used in the military sphere and allow a new approach of collecting, processing, displaying and disseminating spatial information, data and knowledge of the territory for effective using in solving military-application problems related to inventory, analysis, modeling, forecasting and management of troops in the context of military operations. This feature stipulates the necessity of processing, not only geographic information, but also operational information, the main component, which is intelligence information. The addition of operational information to the geographic information systems, as a separate component, leads to increased computational complexity and a decrease in their efficiency. In order to increase the efficiency of the application of special-purpose geoinformation systems, reducing computing complexity and creating application software, the author of this article carried out a comparative analysis of the methods of handling various types of intelligence information in geoinformation systems of special purpose. This article uses the basic provisions of the theory of fuzzy sets, factor analysis, the theory of expert systems, neural networks, artificial intelligence, chaotic time series, spectral analysis methods, and others. According to the results of the comparative analysis of the methods of processing various types of intelligent information in geoinformation systems of special purpose, it has been established, that the most expedient method for obtaining an integrated assessment, based on the analysis of factors presented in numerical and verbal form is to use the method of the theory of fuzzy sets and fuzzy output. The direction of further research should be considered the development of a methodology for processing various types of intelligence information in special-purpose geoinformation systems and the development of a method for configuring the knowledge bases of modern information systems for processing various types of intelligence information in special-purpose geographic information systems, based on a genetic algorithm.

Keywords: *geoinformation systems, intelligence information, operational information, various information, fuzzy set theory, software.*

Introduction

Most of the information, that is required for the successful execution of units of military formations of their tasks is spatially-defined information, which is called geographical.

Technologies of registration, generalization, transmission, transformation and perception of the above information, called geoinformation, allow a new approach to its using through work in the environment of geographical information systems (GIS) –hardware and software man-machine systems, that provide collection, processing , display and distribution of spatial information, data and knowledge about the territory for effective using in solving military-applied problems related to inventory, analysis, modeling prediction and management of troops in the context of hostilities [1].

Practical experience in GIS shows, that not all GIS software products perform the necessary set of functions for the realization of a specific purpose and obtaining practical results.

The suitability of the software is determined by the possibility of performing a number of functions for the complex multivariate implementation of the tasks.

A special feature of special purpose GIS is the availability of not only geographic information, but also operational, the main component of which is intelligence information.

This, in turn, determines the search for optimal methods for processing various types of information.

Therefore, ***the purpose of this article*** is to conduct a comparative analysis of methods for processing various types of intelligence information in geoinformation systems of special purpose.

Exposition of the main material of the research

Taking into account works [2–8], during the study of the results of the large number interaction of raw data, widely using methods of factor analysis (FA).

The essence of the FA allows us to combine a certain number of variables, which describe the received intelligence information. The combination of variables occurs in the process of identifying correlation links between them. As a result of this association, it is possible to identify hidden variables, that were not described in the initial stages of the intelligence. Using these vari-

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ables allows the more complete description of the intelligence information change.

In practice, there are two main types of FA:

reconnaissance – when an object (aggregate of objects) is being investigated, while it is not possible to obtain exhaustive information about all factors, that have influence on the objectivity of the object's identification;

confirming – is used to control the theoretical assumptions about the number and status of the intelligence objects.

Expands the capabilities of the FA various methods of clustering variables, that allow you to distribute all sets of input information about the status of the intelligence object to certain groups. Despite the wide possibilities of the FA in [3–6], his specific limitations are indicated. The limitations of the FA are as follows:

variables (factors f) should have quantitative meaning and formally it is possible to represent it in the form:

$$\forall f \exists n : n \in \{\Re\}, \quad (1)$$

where $\Re$ – plural of real numbers.

the total number of observations has at least twice the number of variables;

sampling of variables should be homogeneous (sometimes obey the normal distribution law);

using possible, when there is a relationship between the variables (correlation).

The analysis of intelligence objects shows, that during the evaluation process, one has to deal with:

factors, that have as numerical characteristics, plurals Φ^{Numb} are technical (measuring) parameters;

factors of the verbal description, Φ^{Verbal}, to the given set include factors, that have qualitative estimation.

Combining the set of factors of quantitative and qualitative assessment, allows you to get more complete information about the objects of intelligence:

$$\Phi = \Phi^{Numb} \cup \Phi^{Verbal}. \quad (2)$$

Thus, from (2), taking into account (1), it follows, that using of FA to describe the objects of intelligence is not appropriate.

As shown by the review of works [9–11] for the exploration of complex systems widely used methods of spectral analysis. The essence is to decompose the output signal by methods of Fourier transformation into a spectrum.

As a result of the decomposition of the output signal on the spectrum, one can obtain its harmonic components having certain amplitudes and periods. Analysis of the parameters of the components allows to allocate cycles in the development of the investigated process.

With regard to the analysis of intelligence, using of the method is limited because:

often evaluated objects are not dependent on each other, that is, it is not possible to construct a curve, that shows changing of objects for a period of time;

factors, that must be taken into account in determining the assessment of an object have different units of measure, may be independent of each other.

As a generalized restriction, it is possible to distinguish the requirement of information on the change of the controlled parameter over a sufficiently long period of time. Taking into account works [9–11], it is desirable to have more than 100 values for obtaining the output signal graph.

Methods, that are based on the using of neural networks are fairly high in the processing of heterogeneous information. The essence of the method lies in the fact, that for processing information using a neural network, which consists of neurons and bonds between them - synapses. Neurons are distinguished by:

input – is given the value of the variable;

hidden (intermediate) of them are the inner layers of the network;

output – is removed the value of output variables.

Inside the neuron, the processing of numerical information occurs through its transformation through the activation function.

While transmitting information (signal) from one neuron to another, it passes through a synapse, the weight of the synapse is a coefficient which, depending on the task, amplifies or weakens the signal coming from one neuron to another.

Formally, the neural network work shown in fig. 1.

$$\beta_{1input} = (\alpha_1 \cdot \omega_1) + (\alpha_2 \cdot \omega_2), \quad (3)$$

$$\beta_{1output} = f\left(\beta_{1_{input}}\right), \quad (4)$$

where α_1 – output value of the first neuron; α_2 – output value of the second neuron; ω_1 – value of the first synapse; ω_2 – value of the second synapse; $\beta_{1_{input}}$ – input value of the second neuron; $\beta_{1_{output}}$ – output value of the second neuron; f – operator of activation function.

In order to use the neural network in the processing of information, it is necessary to teach it.

The essence of the training is to select the weights of synapses in such a way, that the network at the entrance to the input signals from the training sample output signals close to the value of the output signals from the training sample. More details on the using of neural networks for processing information is described in [12]. By the restrictions of the apparatus of neural networks, taking into account work [12] can be attributed:

difficulty in processing information provided in verbal (qualitative) form;

difficulty in interpreting the results of network setup in the learning process;

necessity for the required number of examples in the sample, that is used to configure the network.

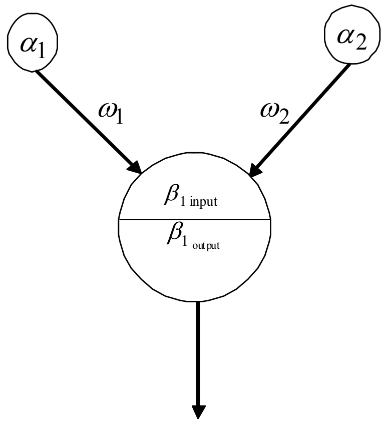

Fig. 1. Formalized description of the neural network operation

Experimental systems [13–14] have widely using for verbal (qualitative) information processing, in which the Delphi method is used to generalize the result [13]. The essence of the Delphi method is to involve a group of experts to prepare a solution to a specific issue.

Peculiarity of the method is the anonymity of the experts at the stages of clarifying the questions for the preparation of the questionnaire and the subsequent direct responses to them, with subsequent approval of replies. If the answers of some experts differ greatly from the opinion of the majority of the group, these answers are sent to other experts for agreement. The limitations of the method include:

high influence of competence and factor of possible bias of experts;

difficulty in protecting the method from the influence of the opinion of the organized group of experts (representatives of one scientific school) on the value of the original result;

necessity of good communication tools between experts in the preparation of the response;

methods of generalization and accumulation of information received from experts are not fully developed.

Thus, one can find the limitations of the method associated with the influence of competence and other features of the expert group on the final result, certain difficulties with the formation and linking of the knowledge base of experts for using in the process of further decision making tasks.

For the account of factors, that have verbal and numerical values, as well as for their generalization in the form of knowledge bases, widely used methods of the theory of fuzzy sets (TFS) and fuzzy logic (FL) [15–29]. A fuzzy set (FS) is called the set M, which consists of a set of elements x, belonging to the supermarket X and values of the degree of membership of the element x to the set M (membership function of the form $\mu_M(x)$) [15]:

$$M = \{(x, \mu_M(x)) : x \in X\}. \quad (5)$$

Combining TFS and logical operations performed over normal sets gave rise to FL and different methods of fuzzy output. FL operations and fuzzy output were widespread in the process of performing approximate calculations [15–29].

The basic concepts of FL are the linguistic variable (LV) and the rules of withdrawal. Under the LV according to [15–29] is a variable, that accepts values from the natural language, such as "Low", "Medium", "Rather, than Medium", "High". LV Fv (fuzzy variable) is denoted as a set of elements:

$$Fv = \{a, T_a, X\}, \quad (6)$$

where a – name of variable; T_a – many values, which takes the variable x, with each of them is a fuzzy variable from the many X, often T_a is called term multiple.

Often in works about fuzzy logic, for example [16], the definition of a fuzzy variable in an expanded form is found, in which, in addition to the described values, procedures for the creation and description of new terms are foreseen. The values of LV are defined by using membership functions (MF), which shows the degree of relationship of the variable value to the terms.

The interaction of fuzzy variables is described by the rules of fuzzy output.

Appointment rule to show the result of the interaction of incoming fuzzy variables. Typically, the interaction of incoming fuzzy variables is described by the operation «$\wedge$ - and» and «$\vee$ - or». An example of the rule of fuzzy output using the operation «$\wedge$», generalized, taking into account works [14–29] is looking as follows:

$$\begin{aligned} Rule_n : if\left(Fv_1^{in} = T_1^1\right) \wedge \left(Fv_2^{in} = T_2^1\right) \wedge \\ \wedge\left(Fv_2^{in} = T_3^2\right) \wedge ... \wedge \left(Fv_b^{in} = T_b^c\right) \Rightarrow Fv_b^{out} = Cv_d, \end{aligned} \quad (7)$$

where b – input number of the fuzzy variable of the considered model; T – value of the term, given by the fuzzy variable; c – term number from the set of terms of the corresponding fuzzy variable; Fv_d^{out} – output fuzzy variable; d – number of corresponding fuzzy variable; Cv_d – numerical (clear) values of the fuzzy variable (Clear value).

The process of fuzzy output, as described in [15–29], consists in performing a sequence of operations:

formation of the set of input variables, as a rule, is engaged by an expert group, that has experience managing the object of modeling;

formation of fuzzy production rules, that describe different variants of interaction of input variables. Formation of fuzzy production rules is carried out by an expert group, which in its qualitative composition can surpass the formation group of the set of input variables. The processing of expert information in the formation of MF and production rules is carried out by the Delphi method [14];

phasification of input variables – the implementation of the transition from the strict value of the input linguistic variable to the fuzzy, taking into account the degree of belonging to a certain number of terms. The terms describe the value of a given linguistic variable. Operation allows you to generalize the input variables for further processing.

Since variables can have both clear and fuzzy meaning, often uses scales for describing the values of fuzzy variables. This allows us to fulfill the condition (2), which, in view of the analysis of works [15–29], is difficult to perform in the process of using factor analysis:

aggregation of conditions – determination the membership value of the input variable to fuzzy rules, taking into account the value of MF;

activation of interim conclusions, based on the current base of fuzzy rules is related to determining the degree of certainty of each fuzzy statement;

accumulation of conclusions is made by combining fuzzy intermediate conclusions for each of the output variables. As shown by works [14–29], many fuzzy models contain one source fuzzy variable;

Dephasing the output of a fuzzy variable, as a result, the fuzzy value will be converted into a clear (numerical) value.

Considering the magnitude of which is formed the effect on the object of management. Practical implementation of phasification, aggregation, activation, accumulation and dephasing operations is usually performed by using various software packages such as Matlab or Fuzzy Tech. The main algorithms of fuzzy output are: Mamdani algorithm, Tsukamoto algorithm, Larsen algorithm, Sugeno algorithm [20].

Summarizing the conducted analysis, we can conclude that in the methods of TFS any “Clear” value, is a special case of fuzzy, provided, that the degree of membership of the value is equal to “1”. The possibility of using fuzzy logic methods for working with "clear" and "fuzzy" variables is confirmed by the theorem, which was proved by B. Kosko [29].

According to the theorem, any mathematical value can be described by methods of the theory of fuzzy sets and fuzzy logic. One of the most significant limitations of fuzzy output systems is the difficulty of building a knowledge base with more, than five factors under consideration, provided, that more terms are used to describe the factor. Generalization of the analysis of information processing methods is presented in tabl. 1.

Taking into account tabl. 1, it is made of the values of the importance of the parameters of each mathematical methods, the results are summarized in tabl. 2.

Table 1

Generalization of the analysis of information processing methods

Name of the method	Short characteristic	Limitation
Factor analysis	Balance estimation of factor sets, ball scoring of sets of levels of factors values, definition of a general assessment taking into account the works of factors on their significance level	Necessity for experts to assess the factors and levels of their significance, the complexity of accounting factors, that have a nonlinear impact on the overall assessment, the complexity of the information processing in a verbal form
Spectral analysis	Representation of the initial value function of the investigated process in the form of a set of sinusoidal components, which allows to detect hidden cycles in the development process	Necessity for a large selection of output process values to build its graphical dependence, the focus on processing information, presented in numerical form
Neural networks	Construction of a mechanism for determining the output variable, based on the input factors due to the value correction of the synapse weights (edges) of the network	Difficulty in the processing of verbally described information, the secrecy of the learning process of the network, neessity for a sufficient number of examples, used for training the network, making it difficult to adjust the network during its operation
Delphi method	Obtaining a generalized assessment of the subject under consideration by the expert group	Dependence of the result from expert opinion
Theory of fuzzy plurality	Summarization of information, presented in numerical and verbal forms through using of the representation of input variables in the form of fuzzy numbers, with subsequent compilation of knowledge base on production rules.	Difficulty in the formation of the knowledge base in accounting for more, than five factors about the object being studied

Table 2

Comparative analysis of evaluation of information processing methods

Criterion / Method	Information processing in numerical form	Information processing in verbal form	Information processing in istered form	Difficulty in processing of information or the complexity of mathematical calculations
Factor analysis	5	2	2	5
Spectral analysis	5	1	1	1
Neural networks	5	4	4	3
Theory of fuzzy sets	4	5	5	4
Delphi method	3	4	4	3

To facilitate the perception of the information, presented in tabl. 2 in tabl. 3, the criteria for applying the appropriate method of information processing are presented.

Table 3

Criteria for pointing out methods of information processing

Name of evaluation	Range of grades	Minimum value of estimation	Maximum value of estimation
Processing of information in numerical form	from 1 to5	1 - not provided	5 - provided from the very beginning
Processing of information in verbal form	from 1 to5	1 - not provided	5 - provided from the very beginning
Processing of information in nitrated form	from 1 to5	1 - not provided	5 - provided from the very beginning
Difficulty in mathematical calculations	from 1 to5	1 – difficulty require special knowledge	5 - operations are quite simple

Summarizing the analysis and taking into account the analysis of work on information processing [15–29], the most expedient is considered the choice of the theory of fuzzy sets methods for the processing of factors for the evaluation of intelligence information, since its application allows us to develop a mechanism for processing information allows to take into account the mutual influence of verbally and numerically described factors, presented in different assessment scales.

Conclusion

In this article, the author carried out a comparative analysis of the methods of handling various types of intelligence information in geoinformation systems of special purpose.

As a result of the analysis, it has been shown, that in the process of processing intelligence information, it is necessary to consider the factors, that have a quantitative description.

As a result, there is a problem of obtaining an integrated assessment, taking into account the factors presented in numerical and verbal forms.

An analysis of information, processing techniques has shown, that the most appropriate method for obtaining an integrated evaluation, based on the analysis of factors, presented in numerical and verbal form is using the method of the theory of fuzzy sets and fuzzy output.

The direction of further research should be considered the development of a methodology for processing various types of intelligence information in special-purpose geoinformation systems and the development of a method for configuring the knowledge, bases of modern information systems for processing various types of intelligence information in special-purpose geographic information systems, based on a genetic algorithm.

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ОБГРУНТУВАННЯ МЕТОДУ ОБРОБКИ РІЗНОТИПНОЇ РОЗВІДУВАЛЬНОЇ ІНФОРМАЦІЇ В ГЕОІНФОРМАЦІЙНИХ СИСТЕМАХ СПЕЦІАЛЬНОГО ПРИЗНАЧЕННЯ

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Геоінформаційні системи все частіше використовуються у військовій сфері та дозволяють по-новому підходити до збору, обробки, відображення і розповсюдження просторової інформації, даних і знань про територію для ефективного використання при вирішенні військово-прикладних задач, пов'язаних з інвентаризацією, аналізом, моделюванням, прогнозуванням та управлінням військами в умовах ведення воєнних дій. Зазначена особливість обумовлює необхідність обробки не тільки географічної інформації, але й оперативної інформації, основною складовою якої є розвідувальна інформація. Додавання оперативної інформації в геоінформаційні системи, як окремої складової призводить до підвищення обчислювальної складності та зниження їх ефективності. З метою підвищення ефективності застосування геоінформаційних систем спеціального призначення, зниження обчислювальної складності та створення прикладного програмного забезпечення автором в зазначеній статті проведений порівняльний аналіз методів обробки різнотипної розвідувальної інформації в геоінформаційних системах спеціального призначення. В зазначеній статті використані основні положення теорії нечітких множин, факторного аналізу, теорії експертних систем, нейронних мереж, штучного інтелекту, хаотичних часових рядів, методів спектрального аналізу та інші. За результатами проведеного порівняльного аналізу методів обробки різнотипної розвідувальної інформації в геоінформаційних системах спеціального призначення встановлено, що найбільш доцільно для отримання інтегрованої оцінки на основі аналізу факторів, представлених в числовий і вербальній формі, використовувати метод теорії нечітких множин і нечіткого виводу. Напрямком подальших досліджень слід вважати розробку методики обробки різнотипної розвідувальної інформації в геоінформаційних системах спеціального призначення та розробку методики настроювання баз знань сучасних інформаційних систем обробки різнотипної розвідувальної інформації в геоінформаційних системах спеціального призначення на базі генетичного алгоритму.

***Ключові слова*: *геоінформаційні системи, розвідувальна інформація, оперативна інформація, різнотипна інформація, теорія нечітких множин, програмне забезпечення.*

ОБОСНОВАНИЕ МЕТОДА ОБРАБОТКИ РАЗНОТИПНОЙ РАЗВЕДЫВАТЕЛЬНОЙ ИНФОРМАЦИИ В ГЕОИНФОРМАЦИОННЫХ СИСТЕМАХ СПЕЦИАЛЬНОГО НАЗНАЧЕНИЯ

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Геоинформационные системы все чаще используются в военной сфере и позволяют по-новому подходить к сбору, обработке, отображению и распространению пространственной информации, данных и знаний о территории для эффективного использования при решении военно-прикладных задач, связанных с инвентаризацией, анализом, моделированием, прогнозированием и управлением войсками в условиях ведения военных действий. Указанная особенность обусловливает необходимость обработки не только географической информации, но и оперативной информации, основной составляющей которой является разведывательная информация. Добавление оперативной информации в геоинформационные системы, как отдельной составляющей приводит к повышению вычислительной сложности и снижения их эффективности. С целью повышения эффективности применения геоинформационных систем специального назначения, снижения вычислительной сложности и создания прикладного программного обеспечения автором в указанной статье проведен сравнительный анализ методов обработки разнотипной разведывательной информации в геоинформационных системах специального назначения. В указанной статье использованы основные положения теории нечетких множеств, факторного анализа, теории экспертных систем, нейронных сетей, искусственного интеллекта, хаотических временных рядов, методов спектрального анализа и др. По результатам проведенного сравнительного анализа методов обработки разнотипной разведывательной информации в геоинформационных системах специального назначения установлено, что наиболее целесообразно для получения интегрированной оценки на основе анализа факторов, представленных в числовой и вербальной форме, использовать метод теории нечетких множеств и нечеткого вывода. Направлением дальнейших исследований следует считать разработку методики обработки разнотипной разведывательной информации в геоинформационных системах специального назначения и разработку методики настройки баз знаний современных информационных систем обработки разнотипной разведывательной информации в геоинформационных системах специального назначения на базе генетического алгоритма.

Ключевые слова: *геоинформационные системы, разведывательная информация, оперативная информация, разнотипные информация, теория нечетких множеств, программное обеспечение.*