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THE FORMATION OF THE COMPONENTS OF THE FUZZY KNOWLEDGE BASE FOR DIGITAL PLAN-SCHEMES OF THE RESULTS OF SATELLITE MONITORING OF AGRICULTURAL LANDS

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ФОРМИРОВАНИЯ КОМПОНЕНТОВ НЕЧЕТКОЙ БАЗЫ ЗНАНИЙ ДЛЯ ЦИФРОВЫХ ПЛАН-СХЕМ РЕЗУЛЬТАТОВ СПУТНИКОВОГО МОНИТОРИНГА СЕЛЬХОЗУГОДИЙ

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Keywords

Identification; fuzziness; space monitoring; informativity; vision system.

Abstract

The methods of forming the components of fuzzy knowledge base in the form of basic digital plan-scheme of territories determined by the morphology of satellite images, natural data and the results of subjective assessments are considered. Variants of implementation of the algorithm of identification of the increased relia-bility taking into account fuzziness of initial data are investigated. During the development of the model of mod-ern monitoring of territories in the interests of economic and social development of the population, it became obvious that the characteristics of the information with which this model should operate, does not correspond to those objects that describe the "deterministic" mathematics, that is, having certainty, accuracy, completeness, isolation, consistency, etc. Man-machine systems (namely, these should include the system of space monitoring) and components of the apparatus of representation of knowledge in them, in reality, reflect those properties of the human model of the world that do not fit into the deterministic mathematics and are characterized by the presence of "non-factors" - incompleteness, lack of accuracy, nonclosure, possibility of contradictions, etc. In this paper we propose a developed and successfully applied in practice by the authors' method of accounting for non-factors in the identification of objects of the Earth's surface. Within the framework of this method, the fol-lowing sequence of actions is performed: a vector three-dimensional model of the reference object is obtained by geometric construction, then, changing its position in space (rotation, reflection, scaling), a number of the above parameters are obtained, which are stored and used in the future for recognition to recreate the corresponding angle of the reference object. The paper considers the importance of non-factors in the process of identification of objects of the earth's surface during monitoring using satellite data, their condition, the variant to overcome the negative impact of different types of fuzzy initial monitoring data and improve the reliability of its results on the principles of quorum reservation is proposed.

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Ключевые слова

Идентификация; нечеткость; космический мониторинг; информативность; система технического зрения.

Аннотация

Рассматриваются методы формирования компонентов нечеткой базы знаний в виде базовых цифровых план-схем территорий, определяемых морфологией спутниковых снимков, натурных данных и результатов субъективных оценок. Исследуются варианты реализации алгоритма идентификации повышенной достоверности с учетом нечеткости исходных данных. В ходе разработки модели современного мониторинга территорий в интересах экономического и социального развития населения, стало очевидным, что характеристики информации, с которой эта модель должна оперировать, не соответствует тем объектам, которые описывает «детерминированная» математика, то есть обладающим определенностью, точностью, полнотой, замкнутостью, непротиворечивостью и т. п. Человеко-машинные системы (а именно к таким и следует отнести систему космического мониторинга) и компоненты аппарата представления в них знаний, в реальности, отражают те свойства человеческой модели мира, которые не вписываются в детерминированную математику и характеризуются наличием «НЕ-факторов» – неполнотой, отсутствием точности, незамкнутостью, возможностью противоречий и т. д. В данной работе предлагается разработанный и успешно примененный на практике авторами способ учета НЕ-факторов при идентификации объектов земной поверхности. В рамках этого способа производят следующую последовательность действий: получают векторную трехмерную модель эталонного объекта путем геометрического построения, затем, изменяя ее положение в пространстве (поворот, отражение, масштабирование), получают ряд вышеуказанных параметров, которые сохраняют и используют в дальнейшем при распознавании для воссоздания соответствующего ракурса эталона объекта. В работе рассмотрено исследовано значение НЕ-факторов в процессе идентификации объектов земной поверхности в ходе мониторинга с использованием спутниковых данных, их состояния, предложен вариант преодоления негативного влияния различных видов нечеткости исходных данных мониторинга и повышения достоверности его результатов на принципах кворумного резервирования.

Introduction

The most part of existing methods of identification of image subjects in vision systems (SVS) [1-4] use idealized (exact) model of information of subject environment of both benchmarks and real images, that significantly limits the accuracy of identification.

As stated in the work [5], during the development of the model of modern monitoring of territories in the interests of economic and social development of the population, it becomes obviously that the characteristic of information, which should be operated by this model, does not correspond to those objects that are described by "deterministic" mathematics, that is, having certainty, accuracy, completeness, isolation, consistency, etc. During the development of the model of modern monitoring of territories for economic and social development of the population, it becomes apparent that the characteristics of the information with which this model must operate, does not correspond to the objects that Describes the "deterministic" mathematics, i.e. possessing certainty, accuracy, completeness, reticence, consistency, etc. Human-machine systems (namely, system of space monitoring should be classified to such type [6, 7]) and components mechanism of knowledge presentation in these systems "reflect those properties of the human model of the world, which are characterized by incompleteness, lack of accuracy, non-ambiguity, the possibility of contradictions, etc." [5].

No-Factors in space monitoring of the territories

No-Factors of the model of the monitoring, as human-machine systems, reflect fundamental differences about objective reality and its model, because developed model is always built taking into account its "innate" features: principal incompleteness and principal possibility of errors and contradictions.

No-Factors associated with incompleteness [8, 9].

1. Underdetermination of common knowledge. Every typical entity in aggregate of common knowledge about environment is presented, usually, as not one (separate) approximation, but system of approximations.
2. Underdetermination of concrete knowledge. In common case available information about fragment of reality is not complete even in frame of fixed system of common knowledge. This incompleteness may apply to types of objects, values, relations between them and etc.
3. Uncertainty of knowledge (current model) leads to necessity to make decisions in condition of uncertainty. It means to use the mechanism of the theory of decision-making in the frame of game theory: probability theory, expert evaluations, minimax strategies and etc.

No-Factors associated with approximateness of model: errors, misconceptions, contradictions Incorrectness of model.

4. Errors and misrepresentation of basic data [9, 10]; errors of the

system: errors of modelling, approximation, interpretation of basic data and results; errors in data base: rules of output and calculations, that are able to lead to incompatible and contradictive conclusions in human-machine systems.

5. Incorrectness associated not only with final accuracy of measuring instruments, but also with underdetermination of measured values. [9, 10, 11].
6. Fuzziness based on fuzzy formalisms [12, 13, 14]. Fuzzy-approach offers to speak in every case about membership function, which is about correlation level of one to another, evaluating it in interval from 1 to 0.

Every of No-factors includes whole series of factors, although reflecting mathematically similar (or even physically related) phenomena, but still different in nature [14 - 16].

Now mathematical theory is the most fully developed and the mechanisms of its realization for fuzzy processing [15]. It is related that No-factors was introduced among the first in the 1950s. Over the past years, several hundred thousand publications have appeared, mainly by Japanese, Chinese and, less often, European and American scientists. These publications describe various nuances of fuzzy mathematics. And it allows using for its processing mechanisms that are designed for work with fuzzy. In addition, uncertainty may be processed by different probabilistic and statistical methods [16].

The most scantily explored No-factors are incorrectness and underdetermination. And, if mathematical theories for work with incorrectness more or less were developed, “because interval arithmetic is necessary in many application areas of human activity, but underdetermination as separate No-factors was highlighted just recently” [10], that reflected as on scientific processing of question as on number of publication about underdetermination.

Methods of identification of the objects of underlying surface with account of No-Factors

Let reference image is kept as vector threedimensional model; the set of parameters for affine transformation is fixed for every such model: rotation angles of the axes x, y, z and scale. This set of paramenters is determined for every model with accounting of the complexity of its form: the more complex the form the more quantity of perspectives is necessary for the most complete description of possible variants of object position in areas for carrying out the most accurate identification.

Produce the following sequence of activity: receive vector threedimensional model of reference object by geometric construction, than, changing its position in areas (turn, reflection, scale), receive the number of mentioned above parameters, which save and use in further identification for recreate the appropriate view of the object reference.

Flat image is presented as two-dimensional massive, its elements are values from 0 to 255 – gradation of gray color.

Besides to these parameters, the set includes an additional correlation of sides of dimensional image of object container and object coded representation, which allows defining its position inside dimensional container. Dimensional container is considered minimal rectangular area on flatness, in which the object images is included. Coding is produced by partition of dimensional container, for example, on 25 identical areas and by definition of presentation of object part in each of them. Thus, 25-bit code of given object perspective in binary view: if the part of object is in areas, it is marked by “one”, in other case is marked by “zero”. The code is received by enumeration of mark values in areas from left to right, from the top to down. These additional parameters substantially reduce the amount of variants considering for recognition.

The input of resolver gives the image represented by the array of pixels in grayscale, that is way every element of array has a value from 0 to 255. The dimension of the array depends on the discretization parameters. The recognition is made as follows: dimensional container of input image of the object is defined, than by method mentioned above is encoded. Based on the sides proportion of dimensional container and received code the set of parameters is chosen from reference base. Than the vector models transformation of referral object is transformed according to the parameters previously installed: turn and scale.

After that, a flat image of the referral model is built, which is compared with the input image by means of a neural network of the perceptron type. The comparison is produced by analyzing the grayscale for each discrete area of the image: per-pixel comparison is made. The module of difference is found for each pair image pixels, which is input in resolver, and for received projection of vector model of reference object and is compared it with threshold value. The received data is given on input of neural network of the perceptron type, in dependence on the value of its activation function the decision about the similarity of the vector model projection of the reference object and the input images is made.

SMART as complex hierarchical system

By uniting set of elements of the geoinformation space into a single system for a targeted set of features, it is always possible to divide this set into subsets, under the conditions of the decomposition theorem of Croun-Roudz, thereby isolating its component parts-subsystems from the system. The consequence of this theorem is such a situation in which “every system with finite number of states can be conveniently coordinated so that the coordinate actions are divided into separate simple types” [17], implemented by a number of subsystems obtained by the allocation from the original system. The decomposition process can be continued to the level of elements.

The division, in which the subsystems obtained by the decomposition of a single source system, is referred to as subsystems of the same level (rank), and subsystems obtained by further decomposition are referred to as objects (subsystems) of the lower level, are called hierarchy. It is possible to decompose into subsystems in different ways for the same system, depending on the rules of combining elements into subsystems.

The number of levels, the number of subsystems of each level can be different, but always an important condition must be fulfilled: subsystems directly included in one system of a higher level, acting together, must perform all the functions of the system in which they are included. In other words, the hierarchical system is the multilevel form of organization of objects with strict correlation of objects of the lower level to a certain object of the upper level.

Model of SMART structure

For a visual representation of the hierarchy of a multi-level system SMART, it is able to use the mathematical model proposed in [7-9]. With regard to this work, we consider its shortened version (Pic.1).

The probability of error in obtaining reliable data from each source of information was estimated [7,9]. Let’s estimate how general probability of correct identification of the earth’s surface object will change with using additional sources of information (operational digital plan-scheme).

Approval is combination of the results of the identification of the territory based on information from satellite system, basic and operational digital plan-scheme [9] and technological accompanying information can increase the probability of successful identification.

Corroboration. To solve this problem, let take collected satellite monitoring for the main source of information, and the other two sources (basic and operational digital plan-scheme, found on basic one with questionnaires for the administration of municipalities and direct users of natural resources) – as a reserve.

To improve the reliability of the monitoring of the object of the territory, it is possible to use the principle of quorum backup of data obtained from various sources, and control its reliability. Let's consider the example of the use of quorum reservation for monitoring of agricultural objects of specific area of the Rostov region.

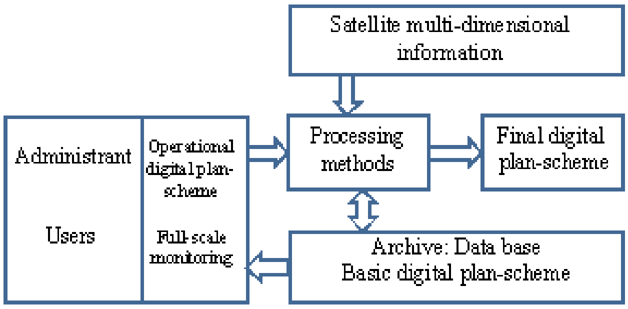


Fig. 1. The structure of the territories monitoring

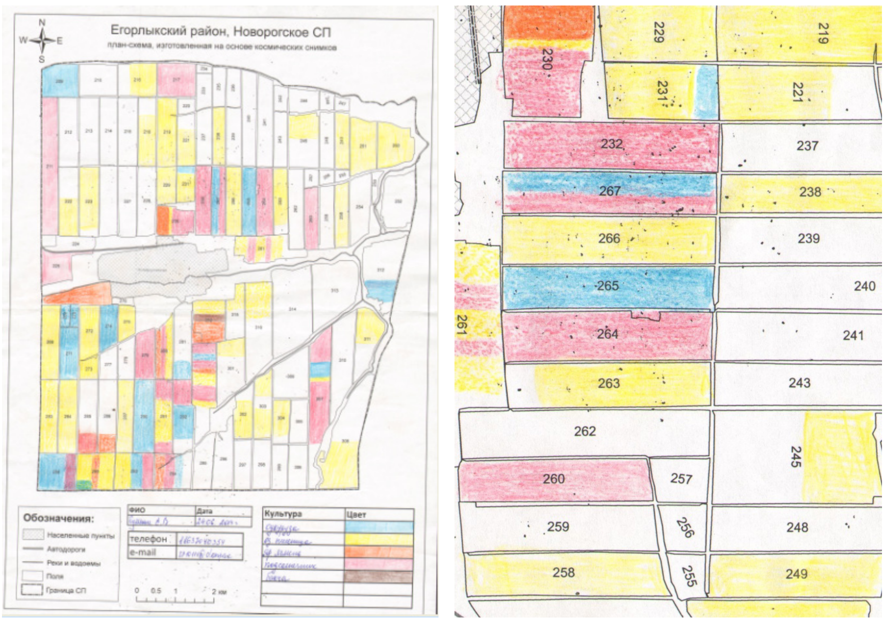
Рис. 1. Структура мониторинга территорий

Table 1. Crops of Novorogovskoe village settlement of Egorlyksky district

Таблица 1. Посевы поселока Новогородское в Егорлыкского района

Field	Crop	Area, ha	Data of sowing	Field	Crop	Area, ha	Data of sowing
209	corn	79	Apr.2013	280	sp.barley	22,2	Apr.2013
211	sunflower	154	May 2013	281	corn	12,4	Apr.2013
217	sunflower	87	May 2013	282	sp.barley	29,6	Apr.2013
225	sunflower	93	May 2013	282	corn	7,4	Apr.2013
230	sp.barley*	14	Apr.2013	301	corn	19	Apr.2013
230	sunflower	52	May 2013	285	sunflower	22,2	May 2013
232	sunflower	72	May 2013	286	sp.barley	22,2	Apr.2013
231	corn	7,4	Apr.2013	290	corn	98	Apr.2013
267	corn	40	Apr.2013	291	sunflower	4,6	June 2013
265	corn	62	Apr.2013	292	sunflower	32	May 2013
264	sunflower	64	May 2013	292	corn	44	Apr.2013
254	corn	7,2	Apr.2013	288	corn	66	Apr.2013
261	sunflower	22,2	May 2013	288	sunflower	22	May 2013
269	corn	25,2	Apr.2013	307	sunflower	50	May 2013
270	corn	29	Apr.2013	307	corn	30	Apr.2013
271	corn	64	Apr.2013	307	sunflower	64,9	May 2013

*spring barley



a) Natural evaluation b) Fragment of natural monitoring

Fig. 2.Variant of source of additional information

a) Естественная оценка b) фрагмент естественного мониторинга

Рис. 2. Вариант источника дополнительной информации

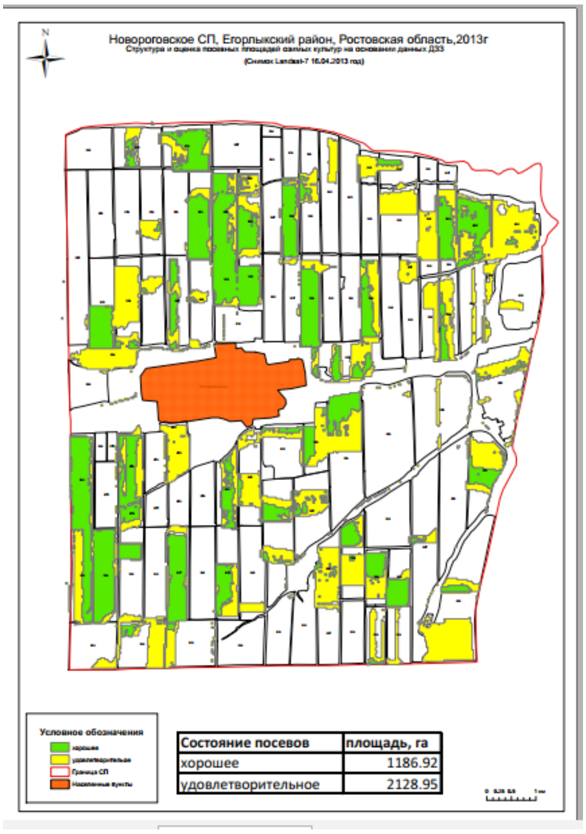


Fig. 3.Variant of final digital plan-scheme

Рис. 3. Вариант окончательного цифрового плана-схемы

If several data sources are used, it is advisable to apply quorum reservation r from s, where s is the number of sources, r is the quorum level [18-21]. Due to the probabilities of proper identification of objects and their position in different sources of information are different, the reliability of the quorum reservation should be calculated by generating function of general theorem about the repetition of the experiments [21, 22].

$$\prod_{i=1}^{n}(q_i + p_i) = \sum_{m=0}^{n} P_{m,n} z^m; \quad P_{r,s} = 1 - \sum_{i=0}^{r-1} {}_{i,s},$$

where $P_{m,n}$ – the probability of m successes in n experiments;
z is random parameter.
For $r = 2$, $s = 3$ $P2{,}3 = 1 - (q1\, q2 + q1\, q3 + q2\, q3 - 2q1\, q2\, q3)$;
for $r = 2$, $s = 4$ $P2{,}4 = 1 - (q1\, q2\, q3 + q1\, q2\, q4 + q1\, q3\, q4 + q2\, q3\, q4 - 3q1\, q2\, q3\, q3)$.
In dependence on how many sub-objects k need to be identified to determine the target objects of the territory, the probability identification error is equal to

$$q_1 = 1 - \prod_{i=1}^{k}(1 - q_i)$$

As the probability of error in the questionnaire (full-scale) list for all objects is considered to be the same, that
$q_2 = 1 - (1 - q_{subject})^k$.
The effectiveness of the reservation can be estimated by using the coefficient of increasing the reliability of the K_{efr} identification
$K_{efr} = q_1/(1 - P_{rs})$.
Let's calculate the efficiency of quorum reservation.
The probability of error in the identification of the state of the earth's surface, for example:

$$q_1 = 1 - \prod_{i=1}^{8}(1 - q_i) = 1 - 0{,}7 = 0{,}3.$$

Let the probability of error of the subject (representative of the administration, land user) in filling of questionnaire list
$q_2 = 1 - (1 - q_{subject})^k = 1 - (1 - 0.01) = 0.08$,
when k - the number of identifiable objects, when $k = 8$.
Then the probability of error in the identification of the object of the earth's surface (for three sources of information):

$$q_3 = 1 - \prod_{i=1}^{3}(1 - q_i) = 1 - 0{,}83 = 0{,}17.$$

Probability of identification success in the redundant system
$P_{2,3} = 1 - (q_1\, q_2 + q_1\, q_3 + q_2\, q_3 - 2q_1\, q_2\, q_3) = 1 - 0{,}03 = 0{,}97$.
Ccoefficient of reservation effectiveness
$K_{efr} = P_{2,3}/(1 - q_1) = 0{,}97/(1 - 0{,}3) = 1{,}39$.
Thus, it is shown based carried calculation, that unification of the monitoring results of territory object based information about its characteristics can increase its reliability by 39% [1, 2, 22].
Promising, in terms of information content, are, as studies have shown [10. 23] vector signs of recognition, called "matrix of the form" [1, 2, 24, 25] based on orthogonal exhibitor, allowing use a generalization of first and second order moments, known from the classical theory of recognition [3. 4].
Thus, the value of No-Factors in the process of identification of earth's surface objects and its states are considered, the variant of overcoming of negative influence of different types of fuzziness of monitoring basic data and increase of accuracy of its results on principles of quorum reservation is offered in the paper.

References

[1] Gvozdev D.S., Lindenbaun M., Khramov V.V., Kovalev S.M. Hybrid model of identification of rolling stock in rail transportation. *Vestnik Rostovskogo Gosudarstvennogo Universiteta Putey Soobshcheniya*. 2013; 2(50):92–98. Available at: https://elibrary.ru/item.asp?id=19020846 (accessed 26.04.2018). (In Russian)

[2] Gvozdev D.S., Khramov V.V., Kovalev S.M., Golubenko E.V. Applied methods of identification in automated transport systems. Rostov-on-Don: RSTU, 2015. 186 p. (In Russian)

[3] Duda R.O., Hart P.E. Pattern Classification and Scene Analysis. N.-Y.: John Wiley & Sons, 1973. 218 p.

[4] Horn B.K.P. Zrenie robotov: Per. s angl. [Robots vision] B.K.P. Horn. M.: Mir, 1989. 487 p. (In Russian)

[5] Khramov V.V. The methods and models of detection and identification of extended objects on earth surface. *Proceedings of the international scientifically-practical Conference "Vehicles: Science, Education, Manufacturing"*. Rostov-on-Don: RSTU, pp. 244-248, 2016. (In Russian)

[6] Khramov V.V., Mitjasova O.Yu. Evaluation of the landscape properties resources mathematical morphology. *Proceedings of the International scientific-practical Conference "Development perspectives and the effective functioning of transport complex in the South of Russia"*. Rostov-on-Don: RSTU, pp.144-146, 2015. (In Russian)

[7] Kramarov S.O., Khramov V.V., Romanchenko V.Yu. Prerequisites of the creation and development of the SMART project (satellite monitoring of agricultural development). *Proceedings of the XIV International Conference "Problems of economy and Informatization of education"*. Tula, pp. 76-82, 2017. Available at: https://elibrary.ru/item.asp?id=29755383 (accessed 26.04.2018). (In Russian)

[8] Golubenko E.V., Khramov V.V., Romanchenko V.Y. Satellite monitoring of territories development as an active ergo technical system: architecture and properties. *Proceedings of the International Conference "Transport: science, education, production"*. Vol. 2. Rostov-on-Don: RSTU, pp. 31-35, 2017. (In Russian)

[9] Akperov I.G., Kramarov S.O., Lukasevich V.I., Povh V.I., Khramov V.V., Radchevskij A.N. Sposob formirovaniya cifrovoj plan-skhemy obektov selskohozyajstvennogo naznacheniya i sistema dlya ego realizacii [Method of forming a digital plan schema objects for agricultural purposes and the system for its realization]. Patent RF, no. 2612326, 2017.

[10] Akperov I.G., Kramarov S.O., Khramov V.V., Mitjasova O.Y., Povh V.I. Sposob identifikacii protyazhennyh obektov zemnoj poverhnosti [Method of identification of extended objects of the Earth's surface]. Patent RF, no. 2640331, 2017.

[11] Kramarov S.O., Smirnov Yu.A., Sokolov S.V., Taran V.N. Methods of analysis and synthesis system intelligently-adaptive management. Moscow: INFRA-M, 2016. 238 p. (In Russian)

[12] Dushkin R.V. Methods for receiving, presentation and processing knowledge with No-Factors. Moscow, 2011. 115 p. (In Russian)

[13] Narinjani A.S. Nedoopredeljonnost in submission and processing systems of knowledge. *Izvestiya akademii nauk SSSR. Tekhnicheskaya kibernetika* = Engineering Cybernetics. 1986; 5:3-28. (In Russian)

[14] Zadeh L.A. Fuzzy Sets. *Information and Control*. 1965; 8(3):338-353. DOI: 10.1016/S0019-9958(65)90241-X

[15] Zadeh L.A. Outline of a New Approach to the Analysis of Complex Systems and Decision Processes. *IEEE Transactions on Systems, Man, and Cybernetics*. 1973; SMC-3(1):28-44. DOI: 10.1109/TSMC.1973.5408575

[16] Zadeh L.A. Fuzzy Logic, Neural Networks, and Soft Computing. *Communications of the ACM*. 1994; 37(3):77-84. DOI: 10.1145/175247.175255

[17] Kramarov S., Temkin I., Khramov V. The principles of formation of united geo-informational space based on fuzzy triangulation. *Procedia Computer Science*. 2017; 120:835-843. DOI: 10.1016/j.procs.2017.11.315

[18] Khramov V. Majority unification of several sources of fuzzy information. Moscow: MIET, pp. 59-61, 1988. (In Russian)

[19] Khramov V.V. Especially the majority fuzzy information processing. Proceedings of the First Russian Conference «Spectral methods of information processing in research» (SPEKTR -2000). M., pp. 136-138, 2000. (In Russian)

[20] Groysman L., Lindenbaun M. Calculation of reliability of the systems with an arbitrary structure with a General reservation quorum. *Izvestiya akademii nauk USSR. Tekhnicheskaya kibernetika* = Engineering Cybernetics. 1974; 2:66-70. (In Russian)

[21] Gvozdev D.S., Khramov V.V. Estimate of probability recognition of the rolling stock units. *Vestnik Rostovskogo Gosudarstvennogo Universiteta Putey Soobshcheniya*. 2010; 4(40):61-66. Available at: https://elibrary.ru/item.asp?id=16398847 (accessed 26.04.2018). (In Russian)

[22] Akperov I., Khramov V., Lukascevich V., Mittjasova O. Fuzzy methods and algorithms in data mining and formation of digital plan-schemes in earth remote sensing. *Procedia Computer Science*. 2017; 120:120-125. DOI: 10.1016/j.procs.2017.11.218

[23] Khramov V.V. Developing a knowledge base for 3D-model railway network Russia. *Proceedings of the International scientifically-practical Conference "Transport-2015"*. Rostov-on-Don: RSTU, pp. 131-133, 2015. (In Russian)

[24] Mayorov V.D., Khramov V.V. Heuristic ways of contour coding of models of information objects in robot vision. *Vestnik Rostovskogo Gosudarstvennogo Universiteta Putey Soobshcheniya*. 2014; 1(53):62-69. Available at: https://elibrary.ru/item.asp?id=21391925 (accessed 26.04.2018). (In Russian)

[25] Khramov V.V. Method of cognitive digital coding of complex information. *Proceedings of the International scientifically-practical Conference "Transport-2006"*. Vol. 2. Rostov-on-Don: RSTU, pp. 40-44, 2006.

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Список использованных источников

[1] *Гвоздев Д.С., Линденбаум М.Д., Храмов В.В., Ковалев С.М.* Гибридная модель идентификации подвижных единиц железнодорожного транспорта // Вестник Ростовского государственного университета путей сообщения. 2013. № 2(50). С. 92–98. URL: https://elibrary.ru/item.asp?id=19020846 (дата обращения: 26.04.2018).

[2] *Гвоздев Д.С., Храмов В.В., Ковалев С.М., Голубенко Е.В.* Прикладные методы идентификации в автоматизированных системах на транспорте. Ростов-на-Дону: РГУПС, 2015. 186 с.

[3] *Дуда Р., Харт П.* Распознавание образов и анализ сцен. М.: Мир, 2012. 511 с.

[4] *Хорн Б.К.П.* Зрение роботов: Пер. с англ. / Б.К.П. Хорн. М.: Мир, 1989. 487 с.

[5] *Храмов В.В.* Многомерный контурный анализ в обработке космических снимков протяженных объектов земной поверхности // Труды международной научно-практической конференции «Транспорт: наука, образование, производство». Ростов-на-Дону: РГУПС, 2016. С. 244-248.

[6] *Храмов В.В., Митясова О.Ю.* Оценка свойств ландшафта местности средствами математической морфологии // Труды международной научно-практической конференции «Перспективы развития и эффективность функционирования транспортного комплекса юга России» (Ростов-на-Дону, 20-21 ноября 2014). Ростов-на-Дону: РГУПС, 2014. С. 144-146.

[7] *Крамаров С.О., Храмов В.В., Романченко В.Ю.* Предпосылки создания и развития средств проекта СМАРТ (Спутниковый мониторинг аграрного развития территорий) // «Проблемы экономики и информатизации образования». Материалы XIV Международной научно-практической конференции / Е.Б. Карпов, С.Н. Шульженко, Г.Н. Лищина. Тула: Тульский университет (ТИЭИ), 2017. С. 76-

82. URL: https://elibrary.ru/item.asp?id=29755383 (дата обращения: 26.04.2018).
[8] *Голубенко Е.В., Храмов В.В., Романченко В.Ю.* Спутниковый мониторинг развития территорий как активная эрготехническая система: архитектура и свойства // Сборник научных трудов международной научно-практической конференции «Транспорт: наука, образование, производство». Том 2. Ростов-на-Дону: РГУПС, 2017. С. 31-35.
[9] Способ формирования цифровой план-схемы объектов сельскохозяйственного назначения и система для его реализации: пат. 2612326 Российская Федерация / И.Г. Акперов, С.О. Крамаров, В.И. Лукасевич, В.И. Повх, В.В. Храмов, А.Н. Радчевский, заявитель и патентообладатель Южный университет (ИУБиП). № 2015105923; заявл. 24.02.2015.
[10] Способ идентификации протяженных объектов земной поверхности: пат. 2640331 Российская Федерация / И.Г. Акперов, С.О. Крамаров, В.В. Храмов, О.Ю. Митясова, В.И. Повх, заявитель и патентообладатель Южный университет (ИУБиП). № 2015153226; заявл. 11.12.2015.
[11] *Крамаров С.О., Смирнов Ю.А., Соколов С.В., Таран В.Н.* Системные методы анализа и синтеза интеллектуально-адаптивного управления. М.: ИЦ РИОР, НИЦ ИНФРА-М, 2016. 238 с.
[12] *Душкин Р.В.* Методы получения, представления и обработки знаний с НЕ-факторами. Москва, 2011. 115 с.
[13] *Нариньяни А.С.* Недоопределенность в системах представления и обработки знаний // Известия академии наук СССР. Техническая кибернетика. 1986. № 5. С. 3-28.
[14] *Zadeh L.A.* Fuzzy Sets // Information and Control. 1965. Vol. 8, issue 3. Pp. 338-353. DOI: 10.1016/S0019-9958(65)90241-X
[15] *Zadeh L.A.* Outline of a New Approach to the Analysis of Complex Systems and Decision Processes // IEEE Transactions on Systems, Man, and Cybernetics. 1973. Vol. SMC-3, issue 1. Pp. 28-44. DOI: 10.1109/TSMC.1973.5408575
[16] *Zadeh L.A.* Fuzzy Logic, Neural Networks, and Soft Computing // Communications of the ACM. 1994. Vol. 37, no. 3. Pp. 77-84. DOI: 10.1145/175247.175255
[17] *Kramarov S., Temkin I., Khramov V.* The principles of formation of united geo-informational space based on fuzzy triangulation // Procedia Computer Science. 2017. Vol. 120. Pp. 835-843. DOI: 10.1016/j.procs.2017.11.315
[18] *Храмов В.* Принятие решений в условиях нечеткой информации. Москва: МИЭТ, 1988. С. 59-61.
[19] *Храмов В.В.* Особенно большая часть нечеткой обработки информации // Доклады I Всероссийской конференции «Спектральные методы обработки информации в научных исследованиях» («Спектр-2000»). Пущино, 24-28 октября 2000. Москва, 2000. С. 136-138.
[20] *Гройсман Л., Линденбаум М.* Расчет надежности систем с произвольной структурой с общим кворумом резервирования // Известия академии наук СССР. Техническая кибернетика. 1974. № 2. С. 66-70.
[21] *Гвоздев Д.С., Храмов В.В.* Оценка вероятности распознавания подвижных единиц железнодорожного транспорта // Вестник Ростовского государственного университета путей сообщения. 2010. № 4(40). С. 61-66. URL: https://elibrary.ru/item.asp?id=16398847 (дата обращения: 26.04.2018).
[22] *Akperov I., Khramov V., Lukascevich V., Mittjasova O.* Fuzzy methods and algorithms in data mining and formation of digital plan-schemes in earth remote sensing // Procedia Computer Science. 2017. Vol. 120. Pp. 120-125. DOI: 10.1016/j.procs.2017.11.218
[23] *Храмов В.В.* Формирование базы знаний для 3D модели сети железных дорог России // Труды международной научно-практической конференции «Транспорт-2015» (Ростов-на-Дону, 21-24 апреля 2015). Ростов-на-Дону: РГУПС, 2015. С. 131-133.
[24] *Майоров В.Д., Храмов В.В.* Эвристические способы контурного кодирования моделей информационных объектов в системе технического зрения робота // Вестник Ростовского государственного университета путей сообщения. 2014. № 1(53). С. 62–69. URL: https://elibrary.ru/item.asp?id=21391925 (дата обращения: 26.04.2018).
[25] *Храмов В.В.* Метод когнитивного цифрового кодирования сложноорганизованной информации // Труды международной научно-практической конференции «Транспорт-2006». Том 2. Ростов-на-Дону: РГУПС, 2006. С. 40-44.

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