The formalization of the characteristics of automatic workplace (AWP) with the use of linguistic variables (LV)

S O Kramarov¹, V V Khramov², A V Belyaev³*, E V Grebennyuk⁴

¹ Institute of Economics and Management, Surgut State University, Surgut, Khanty-Mansi Autonomous Okrug – Ugra, Russia
² Institute of Information Systems, Department of Information Systems and Applied Mathematics, Southern University (IMBL), Rostov-on-Don, Russia
³ Faculty Transportation, Service and Operation, Department of Radio Electronics, Don State Technical University, Rostov-on-Don, Russia
⁴ Polytechnic Institute, Automation and Computer Systems Department, Surgut State University, Surgut, Khanty-Mansi Autonomous Okrug – Ugra, Russia

*Corresponding author: belyaev_a@mail.ru

Abstract. The article suggests using a new approach to formalize requirements and describe them in the form of a fuzzy area in the settings space. To do this, an alphabet is made that contains the values of linguistic variables. Using this method, it is possible to quantify the extent to which the proposed system is part of a variety of effective ARM’s. In this article, the authors used a new solution to apply elements of artificial intelligence and elements of fuzzy logic in the creation of ARM. Using linguistic variables in the article it is possible to determine the degree of belonging of the research system to the effectiveness of this ARM. The method of fuzzy aggregation using linguistic variables (LV) is used in this paper when forming a vector of requirements for an automatic workplace (AWP), as well as its elements, including cognitive analysis methods, a technical description of existing AWPs, their algorithmic and software tools, as well as to determine the degree of compliance of AWP variants with the necessary technical requirements. In this article, we have applied a new approach to formalizing the requirements for determining the effectiveness of ARM use using artificial intelligence and fuzzy logic elements. To do this, we propose to make a special alphabet that contains the values of linguistic variables. Using this method, it is possible to quantify the extent of belonging to many effective ARM’s.

1. Introduction

To date, there is the problem of assessing ARM for specific management tasks that meet the defined technical requirements. Automated Workplace (ARM) is a specialized system, an individual complex of technical and software tools designed to automate the professional work of a particular specialist and provides intelligent analysis of the problem, formalization, preparation, editing, search, intellectually sound output and printing of the documents and data required by him. The ARM consists of four components:

1. Hardware
2. Software
3. Information (databases and know, data banks),
4. Organizational (p.a. and user responsibilities ARM, job descriptions).
ARM as are subject to stringent requirements on a number of parameters. One way to identify/get the necessary specifications is to form a vector of requirements for an automatic workplace. This problem/problem can be solved by using a fuzzy aggregation method using the alphabet of linguistic variables, which allows you to get formalized requirements in the form of a fuzzy vector containing specified parameters, including a quantitative assessment of compliance, which allows you to choose an effective solution with an assessment of its degree.

2. Methods

In the proposed formulation, selection, training and tuning arm the whole system and its structural elements must be uniform, universal and parametric descriptions by the following fuzzy vectors:

\[
\overline{P}_c = [pc_1, pc_2, pc_3, ...];
\]

where \(pc_i\) - fuzzy value of the \(i\)th parameter of the system.

\[
\overline{P}_a = [pa_1, pa_2, pa_3, ...],
\]

where \(pa_i\) - fuzzy value of the \(i\)th partial indicator (score) of the algorithm.

The requirements for the system, subsystems, and functional modules should be presented in the same way:

\[
\overline{P}_t = [pt_1, pt_2, pt_3, ...],
\]

where \(pt_i\) - fuzzy values of the \(i\)th parameter of requirements.

\[
\overline{P}_T = [pT_1, pT_2, pT_3, ...],
\]

where \(pT_i\) - fuzzy value of the requirement for the \(i\)th parameter of the algorithm. Then, by comparing the description of requirements and the actual values of system characteristics, it is possible to conduct a comparative analysis of existing systems and to choose the best one. At the stage of setting up and training the selected system to solve specific tasks of supporting management decisions, taking into account the requirements of relevant plans and programs, orders of Ministers, etc., it is possible to create the most effective routes for processing and analyzing relevant information by comparing and selecting suitable algorithms [1,2].

The description of the procedures for forming requirements for AWP characteristics was carried out in [3,4] on the basis of generalization of technical requirements for AWP support of the management process.

Consider the process of formalizing requirements for AWP as a system. At the stage of forming requirements for the AWP, it is necessary at first create an alphabet of values for the LV "Value". The alphabet must contain all the values of the linguistic variable used in the description of technical requirements for each of the parameters, as well as values that characterize the different degree of their satisfaction.

It is convenient to formalize the technical requirements for the AWP based on the alphabet of values of the linguistic variable (LP), which contains a limited set of values. It can include the following values of the LP "Value": "VERY LARGE", "LARGE", "MEDIUM", "NOT SMALL", "SMALL", "VERY SMALL".

The meaning and quantitative value of linguistic assessments is determined over the entire range of values of the corresponding parameters, taking into account the ongoing rationing. For quantitative estimates, fuzzy aggregation should be possible, i.e. they should be presented in terms of a linguistic variable. Thus, when evaluating the AWP according to the degree of satisfaction of technical requirements, using the fuzzy aggregation method, it is possible to determine whether the considered system belongs to the set of effective AWP and to what extent. Well-known methods of fuzzy aggregation operate with discrete values of the degree to which the parameter belongs to a fuzzy set. In fig.1 the approximation scale of parameter values for the selected LV alphabet is shown.
3. Results

To illustrate the method, consider the case of two parameters: versatility and cost.

In accordance with the generalized requirements, the APM for supporting the management process should have high versatility and low cost. Figure 2 shows the membership function \( \mu_{LV}(p_1, p_2) \) in the normalized two-dimensional space of AWP parameters. The "UNIVERSALITY" parameter is plotted along the abscissa axis \( p_1 \), on the ordinate axis \( p_2 \) - "COST". The membership function is a smooth surface of the second order, which, after performing fuzzy aggregation on a given scale of parameters (fig. 2b), takes a step form. For clarity, the value of the membership function \( \mu_{LV}(p_1, p_2) \) of fuzzy set "LOW COST AND HIGH VERSATILITY" is conventionally represented by intensity gradations. In the zone of low universality, it is close to zero (unsatisfactory), and in the zone of high universality, it is close to one (completely satisfactory).

The points marked on Fig. 2A correspond to several APMs, which are described in [3,5]. It is obvious that in the considered set of AWP, a very small part of the systems belongs to the set of "universal and cheap" with a degree of belonging greater than 0.5 given the fact that the number of parameters used to evaluate AWP is large, the technical requirements for the system can be reduced to a certain hyper-area in the multidimensional parameter space. Moreover, when approaching the center of this area, the degree of satisfaction of requirements increases, and when removing - it decreases. However, the system descriptions themselves in general form also represent fuzzy areas in the parameter space, since they are defined by a fuzzy vector of technical characteristics values (1). Each component of the vector (1) must be represented in a normalized form using the fuzzy aggregation procedure. The alphabet of LV values for each parameter is compiled based on the study of descriptions of all systems involved in the comparative analysis. The algorithm is compiled in the same way as the case discussed above for the AWP requirements. A special feature of the parameter representation is that the LV "Value" often takes quantitative values when forming the AWP description vectors. This leads to a more precise localization of the AWP description area in the parameter space than for requirements.

The space of system parameters is generally n-dimensional. The number of parameters taken into account in the comparative analysis of systems determines the type of fuzzy vectors-descriptions of AWP and the requirements vector. Then the description of the ith AWP variant is represented as a fuzzy vector

\[
\text{Pic} = [p_{i1c}, p_{i2c}, p_{i3c}, \ldots, p_{imc}],
\]

and the description of system requirements - in the form of a vector

\[
\text{Ptc} = [p_{t1c}, p_{t2c}, p_{t3c}, \ldots, p_{tmc}].
\]

In formulas 5 and 6, the upper index indicates that these descriptions and requirements relate to the system (then the index is lowered).

Thus, the formalization of system-wide requirements and AWP parameters was considered. In accordance with the proposed approach, the task of comparing and selecting an AWP to support the
System-wide requirements influence the formation of local requirements for algorithms and routes for processing management information. However, there is no direct relationship between them. To automate the configuration, configuration, and training of AWP, it is necessary to provide a procedure for formalizing internal system requirements for structural and functional elements of the system. The paper suggests using the fuzzy aggregation procedure for this purpose. The principle of formalization of in-system requirements is to extend some of the most significant external requirements for the AWP to its parts and supplement them with requirements for the proper characteristics of these components.

Among the characteristics of algorithmic and software modules proposed to include processing time in most situations occupied by the amount of memory, the compression management information, the quality of treatment results of standard situations and other assessments of the effectiveness of the algorithms.

For example, an estimate of the universality of a system can be represented by a quantitative value. To form local requirements for the universality of an algorithmic module, it is necessary to first perform a linguistic approximation of a similar system-wide requirement and, thus, to determine the values of the closest linguistic variable. Only than it is possible to compare and to rank the modules according to the degree of satisfaction of the requirements. In the case of a qualitative assessment of the system-wide requirement for the universality of the AWP, the transition to the formation of local requirements for the universality of the module is simplified. It consists in redefining the set of values of the base variable (quantitative scale) using the normalization of parameters (5) based on the data on the universality of all modules available in the system.

Similarly, the remaining components of the vector of system-wide requirements are converted and reduced to requirements for algorithmic and software modules.
In addition to the parameters associated with the system-wide description of the AWP, the module description must contain parameters that take into account and evaluate the features of information processing.

Particular attention should be paid to the formalization of estimates of the resulting information, since it is mainly by its type that the effectiveness of the operation is determined and the necessary transformations of management information are selected.

The results of processing standard situations can be evaluated based on completeness, differentiability, and a number of other factors. One of the most informative characteristics of the resulting information is its completeness.

In relation to this characteristic, we consider the formalization of a parameter that evaluates the completeness of individual areas of the resulting information. The corresponding linguistic variable "completeness" has a quantitative scale of values from 0 to 100%. However, it is advisable to describe the information content "in quality" ("VERY LOW", "LOW", "HIGH", etc.) because it is easier for the user to assess the completeness of the resulting information linguistically than numerically. In addition, such a description can have a purely practical application when dividing the resulting information into parts that are homogeneous in information content (segmentation).

To formalize the concept of "completeness", it is proposed to use the LV "magnitude". From a mathematical point of view, the i-th element of the resulting information with the completeness $u_i\%$ corresponds to the degree of its belonging $i \in [0, 1]$ and the fuzzy set.

Depending on the complexity of standard situations, it is recommended to include from two to nine values in the "value" alphabet. For simple contrasting standard management situations, it is possible to limit to two values ("LARGE" and "SMALL"), which correspond to parts of the resulting information with high and low completeness. For complex weakly differentiable standard situations, it is desirable to use a more complete alphabet, including the following LP values: "VERY LARGE", "LARGE", "MORE than AVERAGE", "AVERAGE", "LESS than AVERAGE", "SMALL", "VERY SMALL".

4. Discussion
Fuzzy aggregation of the concept of "completeness" based on this alphabet is defined on the set of values of standard management situations [6]. If a characteristic value of a fuzzy set is assigned to each LV value, then all external information can be approximated in completeness. An example of fuzzy aggregation of the information content scale clearly shows the meaning of this procedure. Similarly, other assessments of the quality of the results of processing standard situations can be determined and, thus, approximation scales of quantitative and qualitative assessments are obtained.

Thus, the use of the fuzzy aggregation method makes it possible to formalize the requirements for algorithms for processing management information in the form of a fuzzy vector:

$$\text{part} = [p_{\text{ai1}}, p_{\text{ai2}}, p_{\text{ai3}}, \ldots, p_{\text{aiL}}],$$  

and their description is in the form of a vector:

$$\text{pai} = [p_{\text{ai1}}, p_{\text{ai2}}, p_{\text{ai3}}, \ldots, p_{\text{aiL}}],$$  

where i - sequence number of the algorithm,

L – the number of parameters taken into account in the comparative analysis of algorithms.

Comparison of algorithms and evaluation of their effectiveness can be made when solving specific problems of management process support using the procedure of fuzzy multiparametric selection of automated control systems (or their subsystems), and individual algorithmic modules participate in it as options (alternatives).

5. Conclusions
The developed approach to formalizing the description of options and requirements allows you to present them in the form of a fuzzy region in the parameter space, compare options with each other, and determine options that meet technical requirements.

A uniform formalized description allows you to move to ranking options in accordance with the degree of satisfaction of technical requirements, which is a measure of the difference between the
description of the AWP and the requirements, which is a key point in solving the problem of selecting the AWP and its elements to support the management process of specific structural divisions of organizations.

References

[1] Afanasjeva, T., Egorov, Y., Savinov, N. About transformations of a numerical time series using a linguistic variable. Advances in Intelligent Systems and Computing. Conference: International Conference on Intelligent Information Systems and Computing. 2018. DOI: 10.1007/978-3-319-68321-8_23.

[2] Cardin, M.-A. An organizing taxonomy of procedures to design and manage complex systems for uncertainty and flexibility. 2013. Conference: Conference on complex systems design and management. At: Paris, France. DOI: 10.1007/978-3-642-34404-6_21.

[3] Cominetti, O., Matzavinos, A., Samarasinghe, S., Kulasiri, D., Liu, S., Maini, P. DitFUZZY: a fuzzy clustering algorithm for complex datasets. International Journal of Computational Intelligence in Bioinformatics and Systems Biology 1(4). 2010. DOI: 10.1504/IJCIBSB.2010.038222.

[4] Kozuba, J., Pil'a, J. Safety of complex aircraft ergatic systems. Transport Problems 14(2):101-110. 2019. DOI: 10.20858/tp.2019.14.2.9.

[5] Kraft, D., Colvin, E. Fuzzy information retrieval. Synthesis Lectures on Information Concepts Retrieval and Services 9(1):i-63. 2017. DOI: 10.2200/S00752ED1V01Y201701ICR055.

[6] Kramarov S O, Khramov V V, Bezuevskaya V A. 2020 Fuzzy Models of Educational Process Management: Digital Transformation (Communications in Computer and Information Science). Т. 1201. Р.78-85. DOI: 10.1007/978-3-030-46895-8_6.

[7] Kramarov S O, Smirnov Y A, Sokolov S V, Taran V N. 2018 Monography System methods of analysis and synthesis of intelligent adaptive management. (Moscow: RIOR: INFRA-M, p.238).

[8] Luqman, A., Akram, M., Alkenani, A., Alcantud, J. C. R. A study on hypergraph representations of complex fuzzy information. Symmetry 11(11):1381. 2019. DOI: 10.3390/sym11111381.

[9] Martinetti, A., Moerman, J.- J. Dongen, L. A. M. Storytelling as a strategy in managing complex systems: using antifragility for handling an uncertain future in reliability. Safety and Reliability. 2018. DOI: 10.1080/09617353.2018.1507163.

[10] Morris, D., Martin, S., To, A. complexity, systems thinking and practice skills and techniques for managing complex systems. 2019. URL: https://www.researchgate.net/publication/335207418_COMPLEXITY_SYSTEMS_THINKING_AND_PRACTICE_skills_and_techniques_for_managing_complex_systems. (Date of application: 20.05.2020).

[11] Munde, A. Fuzzy information measures with multiple parameters. Fuzzy logic based in optimization methods and control systems and its applications. 2018. DOI: 10.5772/intechopen.78803.

[12] Novak, V. The concept of linguistic variable revisited. 2020. DOI: 10.1007/978-3-030-38893-5_6.

[13] Perederii, V., Borchik, E. Actualization of the distributed knowledge base of ergatic system using the method of fuzzy classification. Informatyka Automatyka Pomiary w Gospodarce i Ochronie Środowiska 4(3):3-5. 2014. DOI: 10.5604/20830157.1121328.

[14] Prasath, S S., Ravikumar, S., Suryawanshi, P., Khade, A. Booting of diskless workstation. International Journal of Scientific Research in Computer Science Engineering and Information Technology. 2020. DOI: 10.3268/CSEIT2062118.

[15] Raheja, S., Rajpal, S. Vagueness of linguistic variable // Journal of computing, Volume 2, No. 6, 2010, pp.106-110. ISSN 2151-9617 URL: https://www.researchgate.net/publication/45925406_Vagueness_of_Linguistic_variable (Date of application: 20.05.2020).
[16] Silva, D., Zhang, B., Ayhan, H. Optimal strategies for managing complex authentication systems. Annals of operations research 293(16). 2020. DOI: 10.1007/s10479-019-03270-7.

[17] Skarzauskiene, A. Managing complexity: Systems thinking as a catalyst of the organization performance. Measuring Business Excellence 14(4):49-64. 2010. DOI: 10.1108/13683041011093758.

[18] Skupień, E., Tubis, A. the use of linguistic variables and the FMEA analysis in risk assessment in inland navigation. TransNav the international journal on marine navigation and safety of sea transportation 12(1):143-148. 2018. DOI: 10.12716/1001.12.01.16. (Date of application: 20.05.2020).

[19] Stenin A. A., Gubskiy, A., Polshakova, O. M. Expert evaluation of the ergatic systems operators activity. Radio electronics computer science control. 2013. DOI: 10.15588/1607-3274-2013-1-22.

[20] Vivek S.B. Compact, «fuzzy» information. 2013. DOI: 10.5121/ijcsit.2013.5510.

[21] Wanga, D., Li, Z., Dey, N., Ashour, A. S., Sherratt, R. S., Fuqian, S. Case-based reasoning for product style construction and fuzzy analytic hierarchy process evaluation modeling using consumers linguistic variables. IEEE Access PP(99). 2017. DOI: 10.1109/ACCESS.2017.2677950.