Multiparametric selection of distance learning tools using fuzzy approaches

Sergey Kramarov[1,*], *Vladimir* Khramov[2], *Elena* Grebenyuk[1], and *Alexander* Belyaev[3]

[1] Surgut State University, 628403, Surgut, Lenin Ave., 1, Surgut, Russia
[2] Private educational institution of higher education «Southern University (IMBL)», 344068, Ave. Mikhaila Nagibina 33A/47, Rostov-on-Don, Russia
[3] Don State Technical University, 344003, Gagarin sq., 1, Rostov-on-Don, Russia

Abstract. The changes in connection with the outbreak of the pandemic have made their own adjustments to the educational process, almost simultaneously changing the usual way of full-time education at all levels, from school to higher professional education. The methodology of multiparametric selection of tools for ensuring the necessary quality of training, implemented on the principles of System of Systems, allowing the University to choose the composition and configuration of these tools, and taking into account the fuzziness of the source data, is proposed. Description of IM as fuzzy vectors and a method of evaluating misalignments can be the basis for multi-parameter methods of their choice, providing automated selection of the base set support the educational process. Thus, we can say that the remote format of work, which has entered all levels of the educational environment, is fixed there, and can be adjusted and developed – adapted to the specific conditions of educational institutions.

1 Introduction

In connection with the pandemic and related restrictions, distance learning has become more prevalent in various fields of production and education.

Information systems allowing to organize the workplace of a specialist employee via the Internet have received a new impulse for demand and development.

Educational institutions in a short time were forced to rebuild their work, using the necessary tools - support systems that allow to quickly and efficiently perform a certain set of labor and educational activities, including the use of artificial intelligence. As a rule, intelligent modules (further - IM) are created for the organization of remote work/study, including hardware and software that implement the necessary algorithmic support (further – AS). The management of higher education institutions faced the difficult task of quickly choosing the most appropriate information platform for work in the current conditions. Universities had to make quick, sometimes even experimental, decisions on choosing the most appropriate information platforms or transforming existing ones.

[*] Corresponding author: maoovo@yandex.ru

In this research, we offered a new way to analyze the proposed information platforms to choose the most effective use of them in a particular University.

2 The basic principles of IM analysis

We propose to consider the choice of IM and structure of its algorithmic and software tools for the tasks of maintaining the educational process in higher education in conditions of restrictions on full-time training as a process of multiparametric optimization using fuzzy logic criteria [16,18]. The basis for optimization is proposed to apply the method of fuzzy multi-parameter choice. Its mathematical description becomes possible after formalizing the optimization goal (the "ideal" variant) as a vector of requirements, describing a set of options, and developing qualitative optimization criteria. A mathematical generalized statement of the choice problem can be represented by a set of the following types:

$$\langle V, F, PT, L, W; T, A \rangle, \quad (1)$$

where the source data is assumed to be:
V - many alternative variants;
F - multiple descriptions of alternatives;
PT - the set of outcomes of alternatives;
L - vector criterion for evaluating the outcome;
W - the structure of preferences.
The next step is to build a solution (rule) or algorithm T that allows you to perform the desired action A over a set of alternatives V. The preference structure determines the procedure for comparing scores L(P), and the decision rule (or algorithm) T - the principle of selecting elements from the set V based on the results of comparison in accordance with the required action A. Then the mathematical description of the procedure for selecting IM and its elements will consist in revealing the content of the mentioned above components (1), taking into account the features of the source data.
The uniformity of the description of the system and its elements allows to consider them in general as variants of design solutions. The set of alternatives variants in this case will consist of a finite number of elements:

$$V = \{V_I, i = 1\}. \quad , \quad (2)$$

each of which is described by a fuzzy parameter vector:

$$V_i : \overline{P}_i = [p_{i1}, p_{i2}, \ldots, p_{ij}, \ldots, p_{im}] \quad (3)$$

The ideal option will be described by the requirements vector:

$$\overline{P}_T = [p_{T1}, p_{T2}, \ldots, p_{Tj}, \ldots, \mathrm{p}_{\mathrm{Tm}}] \quad (4)$$

The importance of the requirements parameter is taken into account when setting the preference vector:

$$\overline{W} = [w_1, \mathrm{w}_2, \ldots, \mathrm{w}_\mathrm{j}, \ldots, \mathrm{w}_\mathrm{m}] \quad (5)$$

It is convenient to represent the initial data in general as a matrix of the problem situation:

$$\left\| P_{ij} \right\|; \quad i = \overline{1, n}, \quad j = \overline{1, m}, \tag{6}$$

where P_{ij} - evaluation of the i^{th} variant by the j-parameter;
n - number of used parameters;
m - the number of possible solutions.
The decision-making procedure is proposed to be presented as a sequence of actions for evaluating, ranking and selecting options in accordance with the system of criteria [10].

The set-theoretic approach used in this work to the selection of IM and its elements was based on a gradual narrowing of the set of possible design solutions [12]. The selection stages can be considered as a kind of filters that eliminating out unsatisfactory variants, and the filtering process will be a process of making a decision on the choice of variants in conditions of uncertainty.

Typical links in the decision-making chain are the evaluation of possible options, ranking and subsequent selection among the most preferred ones [11]. Schematically, the four-stage decision-making process is shown in Fig.1, which shows that a narrowing of the initial finite set of introduced restrictions F is at first stage. The result is a set of valid variants $V_d = V \cap F$.

At the next stage, after evaluating the options according to the selected criteria, the set V_d narrows down to the set of rational options $V_e \in V_d$. The set V_r contains the desired solution $S \in V_r$, received by entering additional preferences, or by directly specifying the option [10].

Thus, taking into account the certainty of the parameters of standard tools, the task of selecting options in the context of unclear requirements for a specific application (i.e. for a specific type of University, or even a separate University), in essence, is to choose a system of preference criteria.

An important point in the decision-making process for choosing an option is the selection of evaluation criteria - the evaluation function L. This choice largely determines the nature of the process.

In previous works, the authors investigated General cases of fuzzy benchmarking, in particular, when comparing two fuzzy vectors, based on measures of Euclid and Mahalanobis [1,10,11].

Taking into account the features of the fuzzy set method apparatus, as well as the fact that in this case it is important to have the mutual arrangement of variants on a common scale, rather than the clusterability of these variants, the work uses a measure of mismatch based on the weighted Hamming distance:

$$L_i = \overline{W} \times (\overline{\Pi}_T - \overline{\Pi}_i). \tag{7}$$

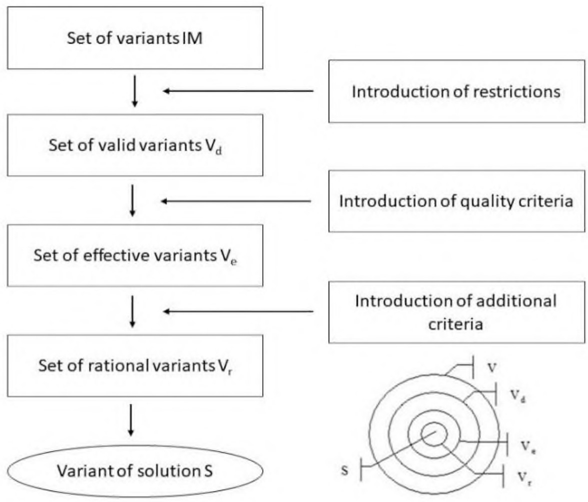

Fig. 1. Method of fuzzy multiparametric selection IM

It is obvious that the inclusion of qualitative, fuzzy (undefined [10]) estimates will lead to a fuzzy total estimate of L and, accordingly, a certain proportion of the risk of making a suboptimal decision. But this uncertainty, along with the uncertainty of quantitative parameters, must be taken into account in the selection process. The presence of a deterministic (D_i) and undefined (F_i) components for i^{th} variants is determined by the formulas:

$$D_i = \sum_{j=1}^{n} W_i l_{ij}^{d} \tag{8}$$

$$F_i = \sum_{j=1}^{n} W_i l_{ij}^{f} \tag{9}$$

If there is uncertainty in the source data, indicator (8) cannot be used explicitly, since it does not provide for working with fuzzy values [2,4-5,11,13,15,18].
Complete mismatch can be expressed as follows:

$$L_i^W = D_i \pm F_i / 2 \tag{10}$$

Using estimates (8) and (9), you can calculate the level of relative uncertainty:

$$\Delta F_i = F_i / D_i \tag{11}$$

Thus, the expression (10) can be chosen as the main criterion for evaluating variants based on the degree of satisfaction of requirements.
The situation of the decision-making scheme for choosing the optimal option can also be represented as a decision matrix, see table 1.

Table 1. Matrix of solutions to problem situations

Variants	$\overline{P}_1$	$\overline{P}_2$	…	$\overline{P}_j$	…	$\overline{P}_m$	D_i	F_i

$\overline{V}_1$	l_{11}	l_{12}	…	l_{1j}	…	l_{1m}	D_1	F_1
$\overline{V}_2$	l_{21}	l_{22}	…	l_{2j}	…	l_{2m}	D_2	F_2
…	…	…	…	…	…	…	…	…
$\overline{V}_i$	l_{i1}	l_{i2}	…	l_{ij}	…	l_{im}	D_i	F_i
…	…	…	…	…	…	…	…	…
$\overline{V}_n$	l_{n1}	ln2	…	l_{nj}	…	l_{nm}	D_n	F_n
$\overline{V}_{\text{тs}}$	$V_{\text{т}1}$	$V_{\text{т}2}$	…	$V_{\text{т}j}$	…	$V_{\text{тm}}$		
Preference vector $\overline{W}$	w_1	w_2	…	w_j	…	w_m		

Each row of the table represents a vector of mismatch (10) of the description of the variant with the requirements. The requirements themselves are shown in a row at the bottom of the table. The structure of preferences is set by a row of weight coefficients for each of the parameters.

The two columns on the right side of the table contain the deterministic (10) and indefinite (11) components of the total estimation of the mismatch of the variant description with the requirements. The data shown in the decision table is the main one for ranking options and choosing the best one.

If we consider the total mismatch (7) as an estimate of a variant, then the entire set of variants can be ranked according to the degree of satisfaction of the requirements. The ranking procedure involves sorting options according to this estimation. The ranking can be based on the average (deterministic), maximum, minimum, and threshold values of mismatch. The choice of a set of effective variants is made based on the condition of minimizing the total mismatch.

Based on the grammar of the linguistic variable "Value", alphabets of values are formed for each of the parameters included in the description, and the characteristic values of the corresponding fuzzy sets are calculated.

Then the empty graphs of the problem situation matrix are filled in with qualitative estimations based on expert knowledge, taking into account the selected alphabets. If there is no information about the parameter under consideration, the linguistic variable "Any" is assigned, which corresponds to the maximum uncertainty of the information.

In steps 1 to 4 of the methodology, initial data is generated for all available IM variants for the selection procedure. The result of this stage of work is the matrix of the problem situation and the corresponding matrix of solutions. For tasks related to the maintenance of the educational process, the corresponding technical requirements for IM are formed, which are the average values for all estimates given by specialists and designers. The analysis of such requirements allowed to make generalized requirements for IM (table 1).

The formation of the vector of preference coefficients (10) is based on the procedures of pairwise comparison and ranking of parameters by their importance (5). The technical requirements vector and the preference vector are part of the terms of reference.

As a result of completing steps 1-4, you can start filling in the solution matrix (table 2), where the values of the simple criterion L_i are calculated by formulas (9-14), and the weighted L_{ni} by formula (10) for all n variants of IM.

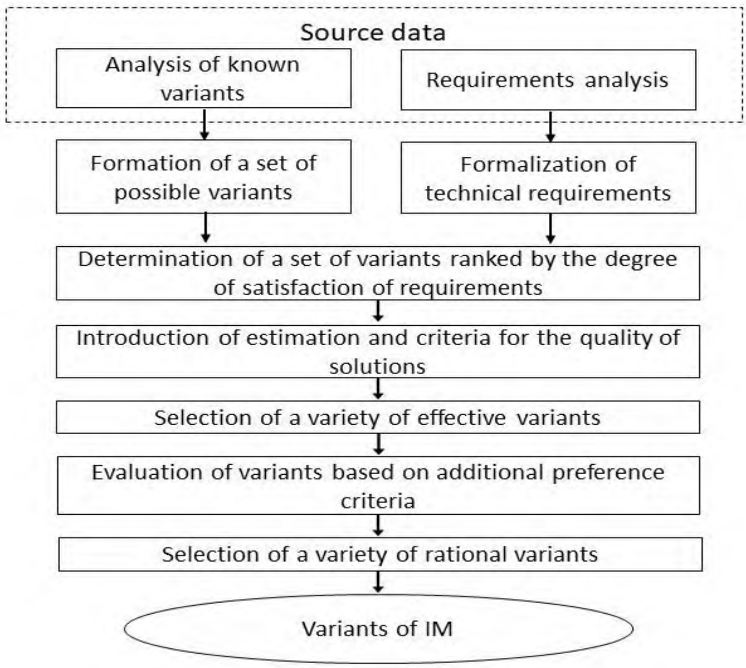

Fig. 2. Diagram of the method for selecting the IM variant

The next steps for the formation of IM are determined by the deterministic (8) and indeterminate (9) components of the criterion (7), as well as the level of relative uncertainty (11) for all *n*. Based on the results of the analysis, the mismatch vectors with the requirements (9) for each of the parameters are calculated, as well as the total "Narrowing" of the set of possible variants V to the set of acceptable values V_d. It is a cross-section of the α-level of the set V. Three different situations may occur at this step, depending on the selection results. If the Vd set is empty, there is no solution. In the future, correction of the criteria (steps 5-6), or rejection to continue the selection procedure are needed. The ideal variant is the case of a single solution, which means the successful completion of the selection procedure of IM. If several elements of the V_d set are found, additional criteria must be introduced (3-6). The parameters are configured according to the algorithm until an unambiguous stable solution appears.

Parametric selection of the variant is an important stage of its implementation IM in the educational process. In accordance with the management task to be solved and the specific training and service conditions, it is necessary to select, build and configure the structure of the software and hardware for IM. The elements of the parametric selection methodology IM used in a modified form when selecting AS structure and the route for processing standard training situations within the selected structure. Let's consider one of the variants of the method described above.

3 Application of fuzzy methods of conducting classes with elements of distance learning based on System of Systems (SoS)

In the modern market of educational services, you can currently find several thousand platforms (portals) of systems that provide their services for conducting classes in remote (distance) mode [2], and not all of them can be used for the effective implementation of the educational process, especially if it concerns various technical and technological laboratory work, which is important for technical universities.

There are separate systems that allow to combine different tools on their sites, including integrative ones, namely, to combine not only different formats (multimedia, office applications, gaming and interactive environments, tests), but also to connect other external applications (for example, proctoring, anti-plagiarism), i.e. systems made in different software languages with different architecture. Such platforms must work together, i.e. they must meet the characteristics of SoS, i.e. they will integrate different tools from different electronic platforms that have different protocols, are written in different software languages, they need plug-ins and shields (extensions) to work together, i.e. they must have elements of interoperability [2], as well as certain properties (ease of use, availability of appropriate tools for working with students, etc.).

Important features of modern distance learning systems are:
- effective provision of electronic course materials to students, both in traditional forms (lectures and seminars) and new ones (self-study, gamification, etc.);
- a subsystem for analyzing test results that allows to draw conclusions about the level of knowledge, as well as the quality of training courses;
- integration with external corporate systems;
- support of modern standards in the field of distance learning technologies, etc. [5,13].

The classification developed by the USA Department of defense identifies four types of system systems: targeted, generally recognized, collaborative, virtual [4] and if we consider the most commonly used distance education systems in the Russian education system: moodle, 1C - enterprise, Cisco Webex Teams, then in accordance with this classification, all of them are generally recognized, since they have a recognized architect who can influence the components of the system for their self-change, according to a given architecture.

According to the criteria developed by Maer [17], SoS must have the following characteristics:
- operational independence;
- administrative independence of its elements;
- emergence from integration into the system;
- evolutionary development;
- geographical distribution of elements;
- a dynamic organizational structure that is able to respond to changes in the environment and changes in goals and objectives, the so-called self-organization;
- a structure that must respond to external changes and perceptions of the environment, so-called adaptation, etc.

Let's evaluate the degree of compliance of the above distance education systems with the criteria listed above, see table 2.

Table 2. Compliance of individual distance education systems with SoS criteria (expert assessments) [13].

System	Moodle	1C	Cisco Webex
Operational independence	1	1	1
Administrative independence of elements	1	0.9	0.8
Emergence from integration into the system	0.3	0.7	0.6
Evolutionary development	0.2	0.9	0.8
The geographical distribution of the elements	1	0.1	0.4
Dynamic organizational structure - self-organization	0.1	0.1	0.05
Adaptation	0.6	0.3	0.3

As a result of almost six months of remote work, this format of work showed/identified both disadvantages and positive aspects in remote/distance education. For example, gaps in methodological developments, lack of corporate rules and etiquette of online communication.

4 Practical applications of the methodology of fuzzy selection of distance learning tools

Let's consider the possibility of analyzing the effectiveness of the above methodology for the following information platforms: Moodle [8], 1C: Enterprise [5], Cisco Webex Teams [6], Docent [9] and Hypermethod eLearning Server 4G [7] on typical examples of regional and federal universities (see table 3-6).

Table 3. Fuzzy selection of distance learning tools: parametric description of the problem (regional University)

Variant of the tool	**Considered parameters of**				
	$\overline{P}1$ roles in the system		**$\overline{P}2$ user languages**	**$\overline{P}3$ support for standards**	**$\overline{P}4$ type of questions**
Moodle	$\overline{V}1$	3	80	3	10
1C: Enterprise	$\overline{V}2$	5	22	1	3
Cisco Webex Teams	$\overline{V}3$	4	16	1	3
Docent	$\overline{V}4$	6	1	1	16
Hypermethod eLearning Server 4G	$\overline{V}5$	7	4	3	10
Requirements vector	$\overline{V}_T$	≥3	≥3	$\tilde{2}$	$\tilde{5}$
Preference vector $\overline{W}$	0.2		0.3	0.2	0.3

Table 4. Fuzzy selection of distance learning tools: parametric fuzzy optimization **(**regional university)

Variant of the tool		**Discrepancies**				**Disagreement**	
		$\overline{P}1$	**$\overline{P}2$**	**$\overline{P}3$**	**$\overline{P}4$**	**Di**	**Fi**
Moodle	$\overline{V}1$	0	0	0	0	0	0
1C: Enterprise	$\overline{V}2$	0	0	0.2	0.6	3	0.22
Cisco Webex Teams	$\overline{V}3$	0	0	0.2	0.6	1	0.22
Docent	$\overline{V}4$	0	0.6	0.2	0	3	0.22
Hypermethod eLearning Server 4G	$\overline{V}5$	0	0	0	0	0	0
Requirements vector	$\overline{V}_T$	≥3	≥3	$\tilde{2}$	$\tilde{5}$	$L_i^W = D_{i\,min} \pm \frac{F_{i\,min}}{2} = 0$	
Preference vector $\overline{W}$		0.2	0.3	0.2	0.3		

Table 5. Fuzzy selection of distance learning tools: parametric description of the problem (federal university)

Variant of the tool		**Considered parameters of**			
		$\overline{P}1$ roles in the system	**$\overline{P}2$ user languages**	**$\overline{P}3$ support for standards**	**$\overline{P}4$ type of questions**
Moodle	$\overline{V}1$	3	80	3	10
1C: Enterprise	$\overline{V}2$	5	22	1	3
Cisco Webex Teams	$\overline{V}3$	4	16	1	3
Docent	$\overline{V}4$	6	1	1	16
Hypermethod eLearning	$\overline{V}5$	7	4	3	10

Server 4G					
Requirements vector	$\overline{V}_T$	≥5	≥5	$\tilde{3}$	$\widetilde{10}$
Preference vector $\overline{W}$		0.3	0.2	0.1	0.4

Table 6. Fuzzy selection of distance learning tools: parametric fuzzy optimization (federal university)

Variant of the tool		**Discrepancies**				**Disagreement**	
		$\overline{\text{P}}$**1**	$\overline{\text{P}}$**2**	$\overline{\text{P}}$**3**	$\overline{\text{P}}$**4**	**Di**	**Fi**
Moodle	$\overline{V}1$	0.6	0	0	0	2	0.18
1C: Enterprise	$\overline{V}2$	0	0	0	0.1	2	0.04
Cisco Webex Teams	$\overline{V}3$	0	0	0	0.1	2	0.04
Docent	$\overline{V}4$	0	0.8	0.4	0.1	4	0.24
Hypermethod eLearning Server 4G	$\overline{V}5$	0	0.2	0	0	1	0.04
Requirements vector	$\overline{V}_T$	≥5	≥5	$\tilde{3}$	$\widetilde{10}$	$L_i^W = D_{i\,min} \pm \frac{F_{i\,min}}{2} = 1{,}02$	
Preference vector $\overline{W}$		0.3	0.2	0.1	0.4		

Thus, as can be seen from the tables, in relation to a typical regional University, Moodle and Hypermethod eLearning Server 4G can be offered as an effective tool, as they have a minimum distance from the vector of their parameters to the fuzzy vector of requirements. In the case of choosing distance learning tools for a Federal University, the only candidate for effective use (from the above examples) in distance learning is Hypermethod eLearning Server 4G tool.

5 Conclusion

1. On the basis of normalization and fuzzy aggregation methods of fuzzy set theory, a single formalized description of the qualitative and quantitative parameters of IM and its components is carried out. Formalization of fuzzy formulated requirements of the technical specification for IM and local requirements for its subsystems in the form of fuzzy vectors allowed us to reduce the procedure for selecting options to the task of searching for the nearest fuzzy regions in the parameter space.
2. For comparative evaluation of IM, a measure of mismatch between fuzzy parameter values was used, and quality indicators of IM variants and their subsystems were formed, taking into account the importance of the requirements of the technical task.
3. Description of IM as fuzzy vectors and a method of evaluating misalignments can be the basis for multi-parameter methods of their choice, providing automated selection of the base set support the educational process.

Thus, we can say that the remote format of work, which has entered all levels of the educational environment, is fixed there, and can be adjusted and developed – adapted to the specific conditions of educational institutions.

References

1. G. I. Akperov, V. V. Khramov, A. A. Gorbacheva, Using soft computing methods for the functional benchmarking of an intelligent workplace in an educational establishment. Advances in Intelligent Systems and Computing, **1095**, 54-60 (2020)
2. L. Bai, J. Choi, Detection for Underdetermined MIMO Systems. Low Complexity MIMO Detection (2012) DOI: 10.1007/978-1-4419-8583-5_6. (Last accessed 06.03.2020)

3. J. Dahmann, J. A. Lane, G. Rebovich, R. Lowry, Systems of systems test and evaluation challenges. IEEE Xplore. Conference: System of Systems Engineering (SoSE). (2010) DOI:10.1109/SYSOSE.2010.5543979. (Last accessed 06.03.2020)
4. E. I. Denisov, A. Eryomin, I. V. Stepanian, V. Bodyakin, Issues of Measurement and Estimation of Information Load at Intellectual Labour. Neurocomputers: Design and Implementation, **10**, 54-62 (2013)
5. E-learning: 1C: Enterprise. 1C, LLC (2020) URL:https://consulting.1c.ru/ (Last accessed 03.04.2020)
6. E-learning: Cisco Webex Teams, LLC (2020) URL:https://www.cisco.com/. (Last accessed 10.04.2020)
7. E-learning: Hypermethod eLearning Server 4G, LLC «Lenvea» (2020) URL:https://hypermethod.ru/ru. (Last accessed 16.04.2020)
8. E-learning: Moodle, LLC (2020) URL:https://moodle.org/. (Last accessed 20.03.2020)
9. E-learning: System of remote education Docent «UNIAR», LLC (2015) URL:http://www.uniar.ru/docent.php (Last accessed 30.04.2020)
10. V. V. Khramov, *Theory of information processes and systems: educational and methodological guide. Rostov State Transport University*, 61 (Rostov-on-Don, 2011)
11. S. O. Kramarov, V. V. Khramov, System engineering approach to research of complex multidimensional systems based on soft models. Intellectual resources to regional development, **4(1)**, 222-228 (2018)
12. J.-E. Mai, The quality and qualities of information. Journal of the American Society for Information Science and Technology, **64(4)** (2013) DOI:10.1002/asi.22783
13. C. B. Nielsen, P. G. Larsen, J. Fitzgerald, J. Woodcock, J. Peleska, Systems of Systems Engineering, ACM Computing Surveys, **48(2)**, 1-41 (2015) DOI: 10.1145/2794381. (Last accessed 08.02.2020)
14. A. Razzaq, L. Swidi, On classification of fuzzy set theory. Journal of Engineering and Applied Sciences, **14(14)**, 4786-4794 (2019) URL: https://www.researchgate.net/publication/343682945_on_classification_of_fuzzy_set_theory. (Last accessed 14.02.2020)
15. R. Sahba, N. Ebadi, Mo M. Jamshidi, P. Rad, *Automatic text summarization using customizable fuzzy features and attention on the context and vocabulary. Conference: 2018. World Automation Congress (WAC)*, (2018) DOI:10.23919/WAC.2018.8430483 (Last accessed 08.02.2020)
16. V. I. Strelchenko, *The problem of the educational value of information. Conference: Proceedings of the 11th International Scientific and Theoretical Conference - Communicative Strategies of Information Society* DOI:10.15405/epsbs.2020.03.02.25 (Last accessed 20.05.2020)
17. K. D. Willett, *systems engineering the conditions of the possibility (Towards Systems Engineering v2.0) Conference: INCOSE International Symposium At: Cape Town, South Africa*. (2020) https://www.researchgate.net/publication/343306942_Systems_Engineering_the_Conditions_of_the_Possibility_Towards_Systems_Engineering_v20 (Last accessed 14.02.2020)
18. H.-C. Wu, Duality in Fuzzy Sets and Dual Arithmetics of Fuzzy Sets (2018) DOI:10.3390/math7010011. (Last accessed 16.03.2020)