Estimation Method of Information System Functioning Quality Based on the Fuzzy Logic

Nadia Vasylkiv[0000-0002-4247-7523], Lesia Dubchak[0000-0003-3743-2432], Anatoliy Sachenko [0000-0002-0907-3682]

Ternopil National Economic University, Ternopil, Ukraine
nvs@tneu.edu.ua, dlo@tneu.edu.ua

Abstract. In the article the analysis of modern researches of information systems is carried out, their basic components and the characteristics influencing their functioning are allocated. Monitoring the activities of service personnel in the supporting part of the system allows identifying and taking into account the shortcomings of the design or system operation in order to achieve a sufficient level of its functioning quality. A fuzzy system for the impact evaluating of the reliability of the information system supporting part on the operation quality is proposed. The input variables of this system are the level of qualification, workload of service personnel and the reliability of the system technical support, and the output - the quality of the information system functioning. Analysis of the modelling and simulation results of this fuzzy system have confirmed its effectiveness and efficiency.

Keywords: information system, quality of information system functioning, service personnel, fuzzy logic, Mamdani fuzzy inference.

1 Introduction

The existence of modern society is impossible without information systems (IS) that comprehensively automate technological processes and functions.

The current stage of information control systems development, that implement information technology, is characterized by increased requirements for ensuring its functioning quality. However, despite the intensive development and implementation of modern technologies and methods used in the information control systems designing, in this area there are still unresolved challenges and problems.

IS quality assurance and improvement are a complex problems, the solution of which has many directions. One of them is the monitoring of service personnel in the support part of the system, the results of which allow to identify and take into account the shortcomings of the system design or operation in order to achieve a sufficient level of IS functioning quality.

Thus, the development of estimation methods for the impact of service personnel on the quality of information systems is relevant.

2 Related Works

Analysis of modern information systems shows their widespread use. Researchers are constantly developing new methods and approaches to building such systems.

With the help of information systems, successful applications are achieved. For example, in the steel industry [1], in climate control systems [2], as well as in the development of information systems for processing biomedical data [3, 4] and others [5]. In particular, the authors emphasize the good results in obtaining biomedical signals with fuzzy logic and the possibility of improving the results using the technique of artificial neural networks [6].

The main features of the control objects are several, including high requirements for the maintenance of technological modes and changes in the basic operating parameters of the control object in its actual operation. In such systems, some authors suggest the use of neural networks [7]. Using developed in [8] information system for dye drying process based on neural network increased overall productivity by 5%. However, neural networks have problem with input learning data, so they cannot be implement in many areas.

Nowadays information systems of fuzzy relations have become widespread. Modern information and measurement systems must operate in conditions of uncertainty for various reasons. Uncertainty measurement is a critical estimation tool. The concept of information structures in the information system of fuzzy relations is described by means of the set vectors that allows investigating of the basic characteristics of such system [9].

The basis of modern methods of designing or managing information systems are methods of artificial intelligence. One of the promising areas is the use of fuzzy logic methods. For example in the article [10] author provides a system of fuzzy rules of production, that describing the logic of the operational-consulting system of experts. Article [11] is devoted to situational management of complex information systems using fuzzy models of correspondence. The authors also described the advantages of such model and approach to solving applied problems.

This approach is also applicable to other information systems, in which a fuzzy relationship is used to describe the degree of objects similarity [12].

One of the promising approaches to solving the problem of evaluation and selection of investment projects is based on the intelligent information systems introduction. Authors [13] developed a such system for the selection of investment projects based on Mamdani fuzzy inference, which gave good practical results.

The validity of the use of artificial intelligence methods is demonstrated by modelling and experimental results in [14].

Thus, the application of fuzzy logic methods allows developing productive and viable information systems.

Today, many studies of the information system success, but only a few studies that have focused on human impact on the success of the information system [15].

In [16] authors developed a method of fuzzy estimation of the information system, which has part of the impact on the functioning quality. It is based on a fuzzy system, the input data of which is the state of reliability for software, hardware and information

support, and the output - the quality of the system. In [17] the approach to measurement of the general estimation of the information system efficiency, which is exposed to negative external influences is offered.

Some authors identify the main characteristics of the information system quality, such as working time and the importance of performing a particular action [18]. This is the basis of the information system, but the authors did not take into account the human impact on the functioning quality.

Authors of [19] conducted a systematic review of the literature and concluded that there are five critical success factors in the development of information system projects: people, project, organization, knowledge and experience. The paper presents the results of the presentation of linguistic variables: "Importance of work" and "Working time", which are the basis of modules for data entry and processing in information systems for analysis and evaluation of professional activity.

Therefore, to analyse the quality of the information system, it is necessary to take into account the main characteristics of system reliability, in particular hardware or software, as well as the human factor, which is not clearly defined. Therefore, to solve this problem it is better to use fuzzy logic methods that shows bellow.

3 Methods and Materials

3.1 Information System Frame

The quality of the information system is the completeness of the properties and characteristics of this system, which provide the ability to meet the stated or probable needs [20]. The reliability of the IS supporting part directly affects its quality.

Three aspects characterized quality: the quality of the information system, the quality of life cycle processes and the quality of support or implementation [21].

Features of modern information systems structure are:

- large number of components;
- multifunctionality;
- the presence of structural, informational and other types of redundancy;
- complex forms of components interconnection;
- significant role of time ratios of separate components failures in serviceability and failures of system;
- availability of advanced maintenance.

Since the quality of the system is determined by its reliability, it is necessary to pay attention to research and improvement of methods to ensure the system quality.

The peculiarities of the information system functioning are [22]:

- each system is multifunctional, the functions of which have different significance and, accordingly, are characterized by different levels of requirements for the reliability of their implementation;

- in many systems some critical situations may arise, which are a combination of failures or errors in the system functioning and can lead to significant violations in the coverage of functions;
- the operation involves various types of its provision and personnel, which may to some extent affect the level of reliability;
- each information system includes a large number of disparate elements (technical, software, etc.), and in the performance of one IS function usually involved several different elements, and the same element can participate in the performance of several functions of the system.

Since the service personnel of the information system is involved in the operation of hardware and software of the system, the main objectives of this study are to determine the factors influencing the quality of the system and develop a fuzzy estimation method of the impact of service personnel on its quality.

For the information system, in conditions of uncertainty of its support type reliability level, changes in its functioning quality are typical [23, 24]. Therefore, in a situation with risk of IS functioning quality reducing in conditions of reliability level uncertainty of its individual components, the most appropriate is the use of fuzzy logic, which allows to control external influences based on some probable values, approximate criteria, fuzzy forecasts and their interdependencies [25].

The advantages of fuzzy systems compared to others are:

- the ability to operate with input data set indistinctly: for example, values that are constantly changing over time (dynamic tasks), or values that cannot be set unambiguously;
- the possibility of fuzzy formalization of evaluation and comparison criteria: operating with the criteria of "majority", "possible", "preferably", etc.;
- the possibility of conducting qualitative estimation of both input data and output results, because the operation is carried out not only the actual values of the data, but their degree of probability and its distribution;
- the ability to quickly modelling of complex dynamical systems and their comparative analysis with a given degree of accuracy: operating on the principles of system behaviour described by fuzzy-methods, first, does not spend much time finding out the exact values of variables and compiling equations describing them, secondly, it is possible to estimate different variants of initial values.

The theory of fuzzy sets makes it possible to apply inaccurate and subjective expert knowledge about the subject area for decision-making without formalizing them in the form of traditional mathematical models.

Using the theory of fuzzy sets, the issues of harmonization of contradictory criteria for design decisions are solved. Fuzzy sets make it possible to apply a linguistic description of complex processes, establish fuzzy relationships between concepts, predict project behaviour, form a set of alternative actions and perform a formal description of fuzzy rules of project decision-making.

The general structure of fuzzy control contains the following components: fuzzification unit; knowledge base; block of decisions; defuzzification unit [25].

The fuzzification unit converts the clear values measured at the output of the control object (in this case the information system) into fuzzy values described by linguistic variables in the knowledge base.

The decision block uses fuzzy conditional (if - then) rules laid down in the knowledge base to convert fuzzy input data into the necessary control effects, which are also fuzzy in nature.

The defuzzification unit converts fuzzy data from the output of the decision unit into a clear value, which is fed to the actuator to control the reliability of the supporting part and, accordingly, the information system quality [25].

3.2 Fuzzy Estimation Method of IS Functioning Quality

An important task is to identify nonlinear dependences, i.e. to design their models based on the results of observations. At the first stage, structural identification is performed. It is the formation of a fuzzy knowledge base, which roughly reflects the nonlinear relationship "inputs - outputs" using the linguistic rules "if-then". These rules are generated by an expert or are obtained by extracting fuzzy knowledge from experimental data. In the second stage, there is a parametric identification of the studied dependence by finding such parameters of the fuzzy knowledge base that minimize the deviation of the fuzzy modelling results from the experimental data. The customizable parameters are rule weights and fuzzy term membership functions.

It is assumed that the dependence model $y=f(X)$ is given by the fuzzy Mamdani knowledge base [25]. We assume that there is also a training sample of M pairs of experimental data connecting the inputs $X_r=(x_{r,1},x_{r,2},...,x_{r,n})$ with the yield y of the studied dependence:

$$(X_r, y_r), r = \overline{1, M},$$

where $X_r=(x_{r,1},x_{r,2},...,x_{r,n})$ is the input vector in the r-th pair of the training sample;
y_r - the corresponding output.
We introduce the following notation:
P - vector of membership functions parameters of input and output variables terms;
W - vector of weight coefficients of knowledge base rules;
$F(P,W,X_r)$ - the result of derivation from the fuzzy Mamdani knowledge base with parameters (P,W) at the value of the inputs H_r.
According to the method of least squares, setting up a fuzzy knowledge base Mamdani is reduced to the following problem of mathematical programming: to find such a vector (P,W) that

$$RMSE = \sqrt{\frac{1}{M} \sum_{r=\overline{1,M}} (y_r - F(P,W,X_r))^2} \to \min.$$

In this optimization problem, the controlled variables P are usually subject to constraints that ensure the linear ordering of the term sets elements. Such constraints do not allow optimization algorithms to make, for example, a fuzzy set "low" more than "high". In addition, the kernels of fuzzy sets should not go beyond the ranges of the corresponding variables. Such restrictions ensure the transparency of the fuzzy

knowledge base after configuration, i.e. the possibility of meaningful interpretation of the rules. As for the vector W, its coordinates should be in the range [0, 1]. If the level of interpretability of the knowledge base is subject to high requirements, the weights of the rules are not adjusted, leaving them equal to 1. An intermediate option is possible, when the weights can take values 0 or 1.

The way to draw fuzzy inference by the Mamdani mechanism can be described as follows [25]:

1) comparison of input data with the values of input membership functions;
2) finding the smallest value of input membership functions for each of the inputs that correspond to the rule base;
3) truncation on the ordinate axis of the functions of belonging to the output of values that exceed the values found in the second step;
4) finding among the truncated membership functions the output of those with the maximum amplitude;
5) finding the sum of the values of the cut-off function of the yield found in the fourth step, which forms the final figure;
6) finding the centre of gravity of the obtained figure, which interprets the output of the system.

It is recommended to include in the list of influencing factors of possible deterioration of the information system caused by its supporting part those components that significantly affect its quality. Therefore, it is expedient to distinguish service personnel and their impact from all types of IS support, for example, on the reliability of the technical component and on the functioning of the system as a whole.

The fuzzy system of estimation the impact of the reliability of IS supporting part on its functioning quality has input values of the level of qualification, workload of service personnel and the reliability of the system technical support.

The output of the developed fuzzy estimation system is its functioning quality.
In general, the fuzzy estimation system has the form shown in Figure 1.

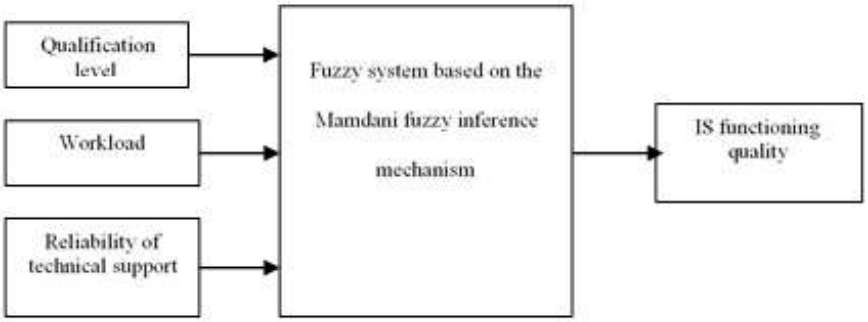

Fig. 1. Fuzzy estimation model of IS functioning quality

The Fuzzy Logic Toolbox MATLAB is used to build and verify the correct operation of the developed fuzzy model. The general scheme of this fuzzy model is given in Figure 2.

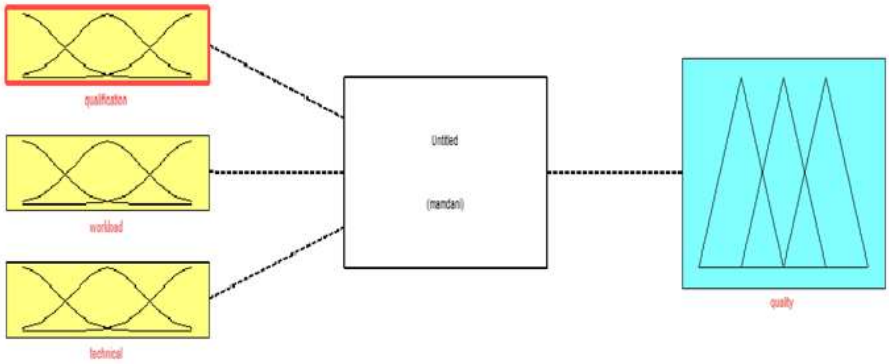

Fig. 2. Fuzzy system developed in MATLAB environment

For the input variable that determines the reliability of hardware, the following distribution is proposed:

- working condition (failure);
- refusal;
- error.

Failure is a property of the object continuously maintain a workable status in the period of some time or some work.

Refusal is an event that represents a violation of the technical support capacity. It is mainly caused by physical destruction of elements or gradual deterioration their characteristics.

Error – short-term disruption to the correct operation of the computing device or its element, after which its operability is self-renewing or restored by the operator without repair. Errors can be triggered by internal or external blockages.

The main qualities of computer technology, related to its reliability, are described by the distribution of failures over time, recovery processes and organization of service.

For the input variable "qualification level" of the staff, it is proposed to consider two states: sufficient and low.

The reliability of the functions assigned to the staff depends on the workload of its work, which may be within the norm or overtime, determines the two possible states of the input variable "workload".

To simplify the construction of a fuzzy system and to speed up its work, you should choose the following distribution of the quality of the information system: high; average; low.

This distribution is used to specify the input variables, i.e. to build their membership functions.

Fuzzy Logic Toolbox graphics tools are used to review the results of the development and operation of the fuzzy inference system. The same tools are used in the development of fuzzy inference systems as a graphical object-oriented automatic programming language.

These tools include:

- FIS Editor (FIS);
- Membership Function Editor (MFE);
- Rule Editor;
- Rule Viewer - fuzzy inference system rules viewer;
- Surface Viewer - fuzzy output surface viewer.

In the case of the developed system, it is expedient to set the membership function of input variables in a bell-shaped form, which will describe them as accurately as possible.

The fuzzy system of distribution of IS functioning quality on an input receives value:

- reliability of technical support (*technical*);
- level of personnel qualification (*qualification*);
- *workload*.

The output of the fuzzy system is system functioning quality (*quality*).

4 Case Study

4.1 Experiment Technique

To specify the membership functions of each variable, it is necessary first determine their range of values.

In order to study the proposed fuzzy system, the reliability of hardware can be set, for example, in the range [0, 1], dividing it into subsets:

- workable;
- crash;
- refusal.

The assignment of the membership functions of the input variable by means of the Membership Function Editor of the MATLAB environment is given in Figure 3.

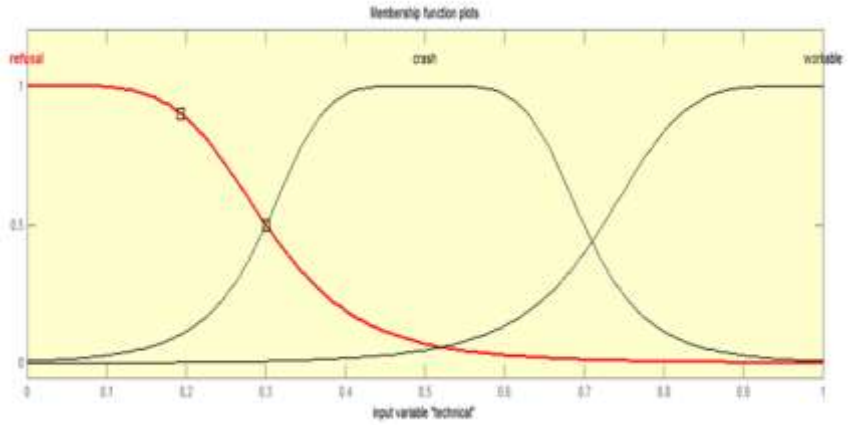

Fig. 3. The membership functions of the input variable “technical”

The input variable of the fuzzy qualification system is specified by the following fuzzy sets:

- sufficient;
- low.

The constructed membership functions of the input qualification variable are shown in Figure 4.

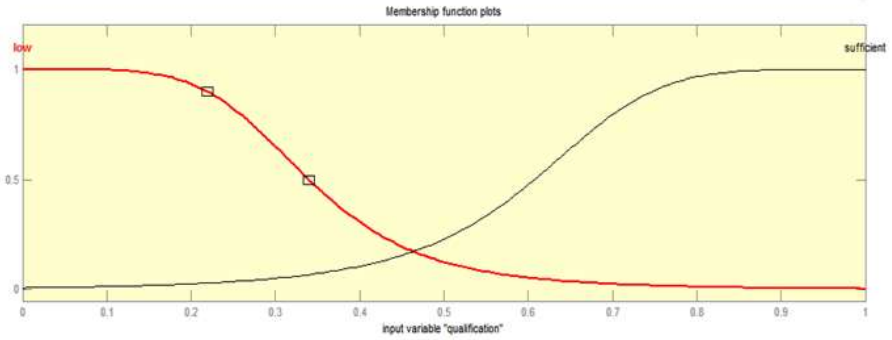

Fig. 4. Functions of membership of the input variable “qualification”

The input variable workload of the developed fuzzy system can be set by the following fuzzy sets:

- overdone;
- normalized.

The membership functions of the input variable workload are shown in Figure 5.

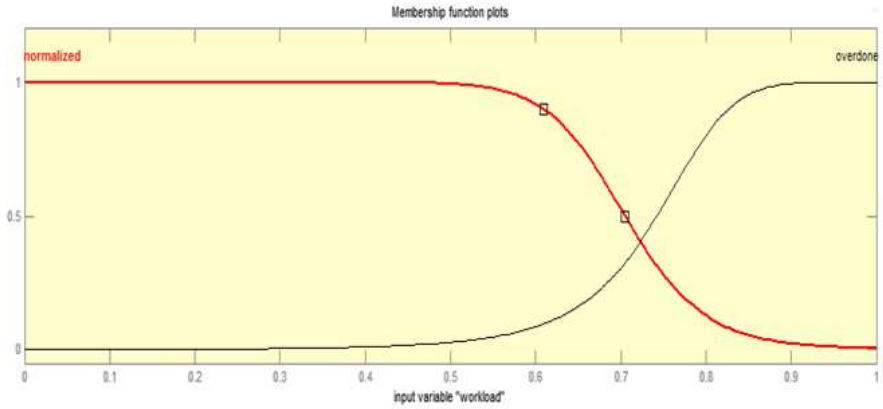

Fig. 5. Membership functions of the input variable "workload"

A trapezoidal shape (Figure 6), which will allow more accurate dephasing gives the membership functions of the output of the developed fuzzy system.

In this case, the output of the fuzzy system interprets the quality of the information system. Fuzzy set "middle", indicates the average value of quality caused by a decrease in the level of technical support reliability or maintenance personnel.

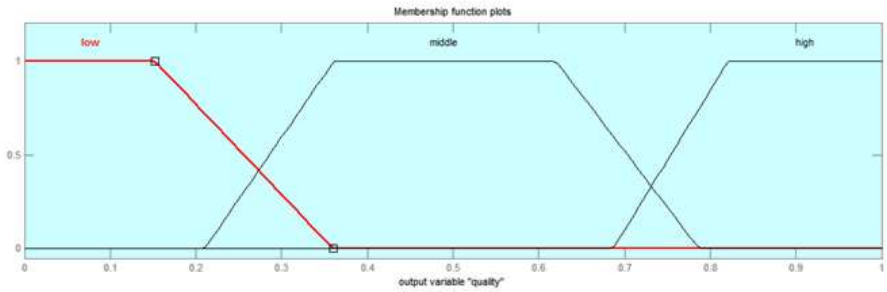

Fig. 6. Membership functions of the output "quality"

If the quality of the system is high, then the output variable of the fuzzy system is set by the set "high", which reflects the range of values [0,7; 1]. If the quality is low, then the output of the developed fuzzy system is set by the set "low".

The operation of the proposed fuzzy system depends on the base of rules. Since the input variables qualification and workload are given by two membership functions, and the input variable technical - three, and given the situation when the level of qualification, workload and reliability of hardware are not specified by the computer system, the rule base consists of R = 3 • 3 • 4-1 = 35 "if-then" rules. The case when not all input variables are specified cannot be considered, because then the fuzzy system cannot give an output inference.

The base of rules is in accordance with the data in Table 1.

For example, if the technical support takes the value that belongs to the working group, the level of qualification is sufficient, and the workload of staff is overtime, it can be assumed that the IS functioning quality will be high.
That is, the rule that describes this case will look like:

If (technical is workable) and (qualification is sufficient) and (workload is overdone) then (quality is high)

Table 1. Correspondence of input and output variables of the developed fuzzy system

Qualification level (qualification)	**Workload**	**Reliability of technical support (technical)**	**IS functioning quality (quality)**
Sufficient	Overtime	workable	high
Sufficient	Overtime	refusal	low
Sufficient	Overtime	failure	low
Sufficient	normalized	workable	high
Sufficient	normalized	refusal	average
Sufficient	normalized	failure	average
Low	Overtime	workable	average
Low	Overtime	refusal	low
Low	Overtime	failure	low
Low	normalized	workable	high
Low	normalized	refusal	low
Low	normalized	failure	low
None	Overtime	workable	average
None	Overtime	refusal	low
None	Overtime	failure	low
None	normalized	workable	high
None	normalized	refusal	low
None	normalized	failure	average
Sufficient	None	workable	high
Sufficient	None	refusal	low
Sufficient	None	failure	average
Low	None	workable	average
Low	None	refusal	low
Low	None	failure	low
Sufficient	overtime	none	low
Sufficient	normalized	none	average
Low	overtime	none	low
Low	normalized	none	average
sufficient	None	none	average
Low	None	none	low
None	None	workable	average
None	None	refusal	low
None	None	failure	low
None	overtime	none	low
None	normalized	none	average

The window for modelling the rule database of the Rule Editor tool of the MATLAB 7.10.0 environment (R2010a) is shown in Figure 7.

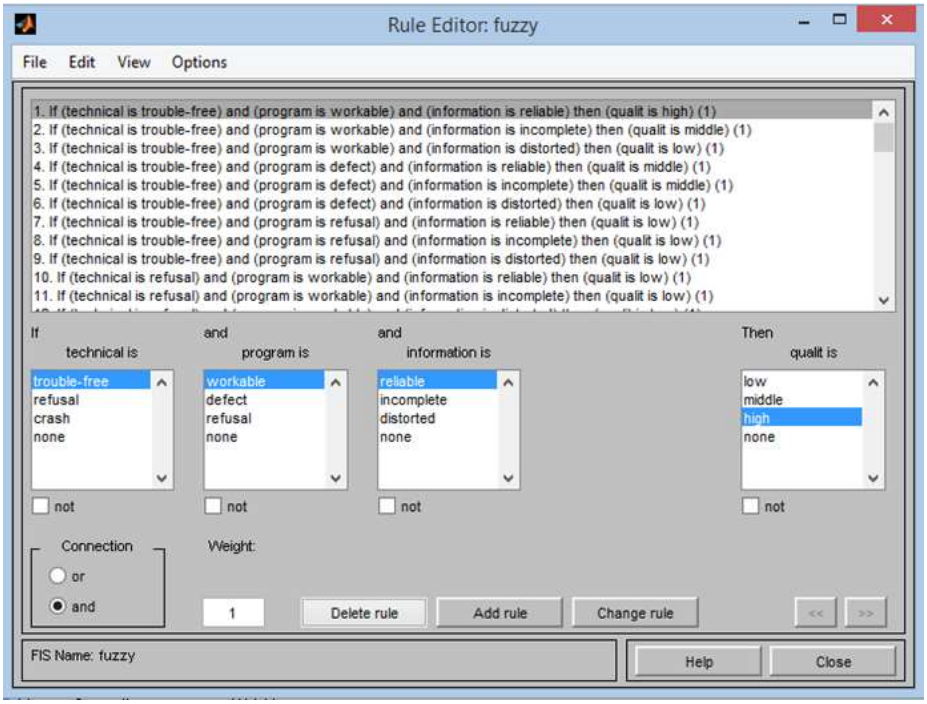

Fig. 7. Rule Editor database creation window MATLAB 7.10.0 (R2010a)

During this database constructing, the correspondence of input and output variables of the developed fuzzy system has been used (see Table 1).

All rules have the same priority, so each of them has a weight of 1 (see Figure 7).

5 Experiment Results and Discussion

To verify the correctness of the developed fuzzy estimation system of IS functioning quality due to service personnel, a tool for reviewing the rules of the fuzzy inference system is used (Figure 8).

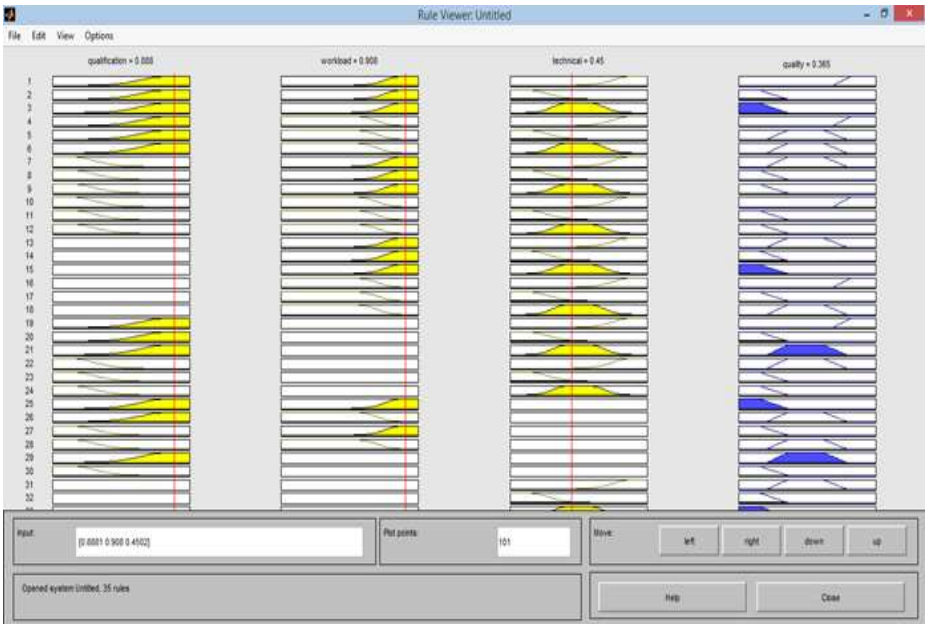

Fig. 8. The result of the fuzzy system

To visualize the dependence of the output variable on the input, the fuzzy output surface viewer is used (Figures 9-11).

As a result of processing the database of rules, we can build a table of input variables values and their corresponding values of the output variable (Table 2).

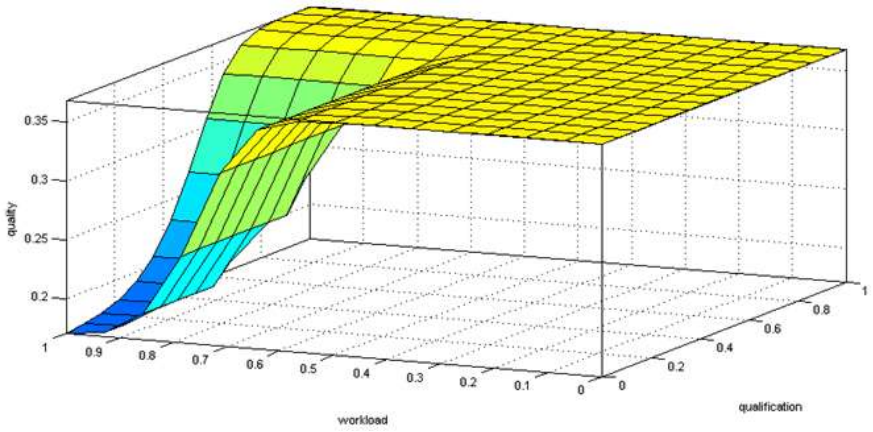

Fig. 9. Surface of the output dependence on the input variables “qualification” and “workload”

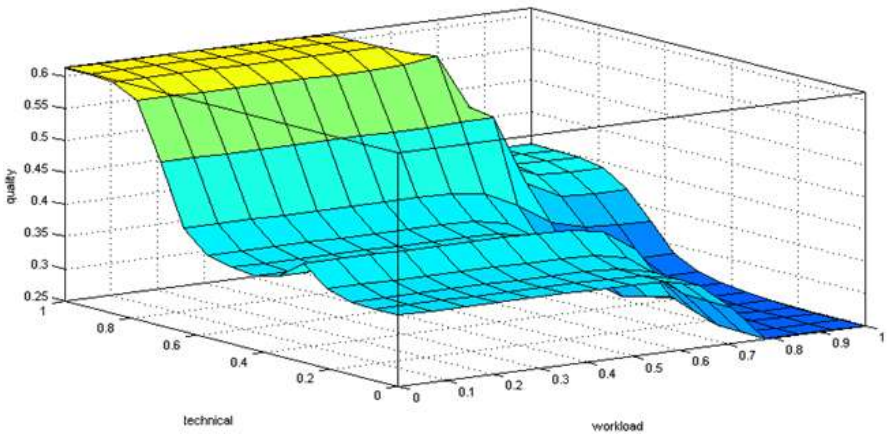

Fig. 10. Surface of the output dependence on the input variables “technical” and “workload”

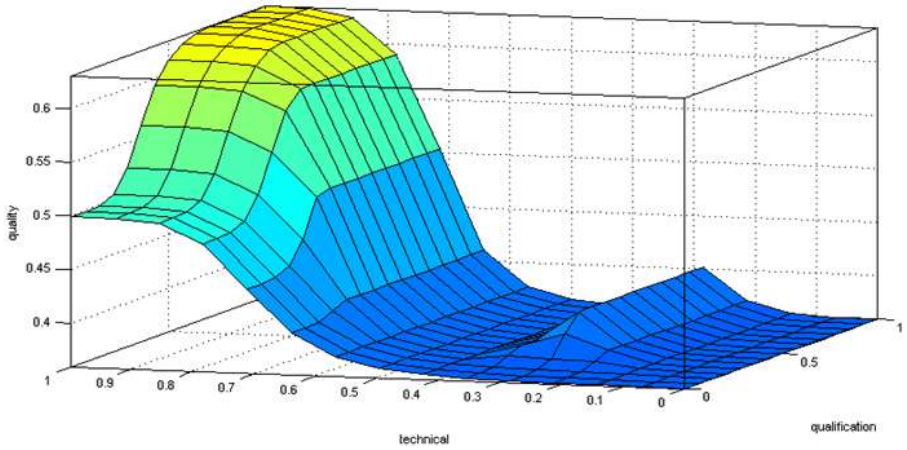

Fig. 11. Surface of output depending on the input values “technical” and “qualification”

Table 2. The simulation results of a fuzzy estimation system

Qualification level	Workload	Reliability of technical support	Quality of IS functioning
0.888	0.908	0.45	0.365
0.0764	0.254	0.879	0.498
0.328	0.0665	0.14	0.361
0.909	0.894	0.929	0.5
0.919	0.0567	0.939	0.631
0.928	0.946	0.865	0.497

The analysis of the data of the case 9 – 11 and Table 2 confirms the correctness of the proposed fuzzy system model.

6 Conclusions

The developed method for estimation of the service personnel impact on the quality of the information system functioning allows taking into account in real time variable influence factors on quality by simulating the situation:

- at any time during the system functioning;
- if necessary, estimation the reliability of the supporting part of the system;
- in the event of a sudden change in the reliability of some type of information system;
- when changing the service personnel of the system;
- when considering and analysing the prospects for system improving.

The fuzzy logic of project decision-making is complicated by the presence of three or more influencing factors. For example, hardware redundancy may be an additional circumstance. This means that the inclusion of a reserve at a certain stage of IS operation in the event of a hardware failure may keep the system at the appropriate level of quality. If the unfavourable circumstances become more and more devastating, the hardware reserve decreases and the quality begins to fall again. It was shown that such complex dependence in fuzzy logic could be represented as a "plateau".

In fact, the "plateau" effect occurs infrequently. A risk situation is more typical, when one of the factors (it can be, for example, workload and fatigue caused by it) affects the reduction of quality from time to time under uncertain circumstances. In this case, the surface of values more realistically reflects the situation and allows making more flexible and sound decisions based on fuzzy logic, i.e. in many variable and uncertain circumstances, such as erroneous actions of staff.

The proposed method will allow management, without having sufficiently accurate and clear information, to estimate the impact of service personnel of the information system on its functioning quality.

In future, the authors plan to investigate the proposed method of influencing the information system quality due to set of components such as technical, software, information support and attendants staff.

References

1. Yang, Y., Chen, Y., Yang, J.: Development of the cross-linked integrated information system. In: Proceedings of the 2017 IEEE International Conference on Industrial Technology (ICIT), Toronto, ON, 1147-1152. (2016)
2. Gorbunov, V., Bobrikov, D., Balashov, A.: Information system for room's technological processes management based on fuzzy logic. In: Proceedings of the 2016 IEEE NW Russia Young Researchers in Electrical and Electronic Engineering Conference (EIConRusNW), St. Petersburg, 203-205. (2016)
3. Dubchak, L., Verbovyy, S., Berezska, K., Datsko, T.: Fuzzy knowledge base for diagnosing breast cancer pathological processes. In: Proceedings of the 2017 12th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), Lviv, 36-39. (2017)
4. Berezsky, O., Dubchak, L., Pitsun, O.: Access distribution in automated microscopy system. In: Poceedings of the 2017 14th International Conference The Experience of Designing and

Application of CAD Systems in Microelectronics (CADSM), Lviv, Ukraine, 241-243. (2017)
5. Vasylkiv, N., Dubchak, L., Lendyuk, T., Turchenko, I., Shylinska, I., Aleksander, M.: Tasks distribution for students testing based on fuzzy logic. In: Proceedings of the 2017 9th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), Bucharest, Romania, 26-29. (2017)
6. Klypin, D.N., Potapov, I.V., Titov, D.A., Garaeva, A.A.: The base tasks in the development of Biomedical Data Information System. In: Proceedings of the 2016 Dynamics of Systems, Mechanisms and Machines (Dynamics), Omsk, Russis, 1-4. (2016)
7. Yang, S., Qiao, L., Sun, B.: Research on Dynamic Intelligent Recovery Based on Power Information System. In: Proceedings of the 2019 International Conference on Computer Network, Electronic and Automation (ICCNEA), Xi'an, China, 307-312. (2019)
8. Artemova, S.V., Artemov, A.A., Ladynin, A.I., Kamenskaia, M.A.: Drying Control Information System. In: Proceedings of the 2020 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus), St. Petersburg and Moscow, Russia, 597- 601. (2020)
9. Li, Z., Zhang, P., Ge, X., Xie, N., Zhang, G., Wen, C.: Uncertainty Measurement for a Fuzzy Relation Information System. In: Proceedings of the IEEE Transactions on Fuzzy Systems, Vol. 27 (12), 2338-2352. (2020)
10. Eliseev, A.V.: Adaptation of Structure of Information-Measuring System Based on Fuzzy Logic. In: Proceedings of the 2019 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon), Vladivostok, Russia, 1-6. (2019)
11. Rakhmatullaev, M.: Situational Management of Complex Information Systems Based on Fuzzy Correspondence Models. In: Proceedings of the 2019 International Conference on Information Science and Communications Technologies (ICISCT), Tashkent, Uzbekistan, 1-4. (2019)
12. Wang, Y., Guan, Y., Xu, F., Wang, H.: The computing approach for attribute reducts of information systems based on fuzzy matrix. In: Proceedings of the 2017 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), Guilin, 1216-1221. (2017)
13. Kondratenko, Y., Kondratenko, G., Sidenko, I., Taranov, M.: Intelligent Information System for Investment in Uncertainty. In: Proceedings of the 2019 10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), Metz, France , 216-221. (2019)
14. Ding, M., Zhang, T., Ma, F., Yue, D.: An incremental algorithm for rapidly computing tolerance class of incomplete information system. In: Proceedings of the 2016 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD) , Changsha, 1296-1300. (2016)
15. Suryanto, T.L., Setyohadi, D.B., Wibowo, N.C.: Empirical investigation on factors related to individual of impact performance information system. In: Proceedings of the 2017 4th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI), Yogyakarta, 1-6. (2017)
16. Vasylkiv, N., Dubchak, L., Turchenko, I., Ivashchuk, I., Savchyshyn, R.: Fuzzy Estimation Method of Information System Providing Part Influence on the Functioning Quality. In: Proceedings of the 2019 10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems : Technology and Applications (IDAACS), Metz, France, 980-984. (2019)
17. Gromov, Y., Minin, Y., Eliseev, A., Habib Alrammahi, A.A., Sari, F.A.: Overall Score of Information System Perfomance and Selection of Synthesis Problem. In: Proceedings of the 2019 1st International Conference on Control Systems, Mathematical Modeling, Automation and Energy Efficiency (SUMMA), Lipetsk, Russia, 377-382. (2019)

18. Zaritskiy, O., Pavlenko, P., Tolbatov, A.: Data representing and processing in expert information system of professional activity analysis. In: Proceedings of the 2016 13th International Conference on Modern Problems of Radio Engineering, Telecommunications and Computer Science (TCSET), Lviv, 718-720. (2016)
19. Edwita, A., Sensuse, D.I., Noprisson, H.: Critical success factors of information system development projects. In: Procedings of the 2017 International Conference on Information Technology Systems and Innovation (ICITSI), Bandung, 285-290. (2017)
20. DSTU ISO 9000: 2007. Quality management system. Basic provisions and dictionary [Text]. - Enter. 2008-01-01. - Kyiv: State Standard of Ukraine, 72 (2001)
21. Information systems in management: textbook. Glivenko, S.V., Lapin, E.V., Pavlenko, O.O., Slabko, S.S., Lebid, V.M. Sumy: University Book, 407. (2005)
22. Myers, G.: Software reliability. - M .: Myr, 269. (1980)
23. Fundamentals of software systems quality engineering. Andon, F.I., Koval, G.I., Korotun, T.M., Lavrishcheva, E.M., Suslov., V.Y. K.: Akademperiodika, 672. (2007)
24. Wexler, E.M.: Quality management: K.: Lybid, 432. (2008)
25. Design of information systems: Solovjov, I.V., Majors, A.A.: M.: Akademicheskiy Proekt, 400. (2009)