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ASSESSMENT OF THE FUZZY STATE OF COMPLEX SYSTEMS

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Abstract. The paper considers the problem of estimating the state of the enterprise (on example of the IT company). The problem is presented in the form of two problems. The first problem is the aggregation of the initial information and the second problem is the identification of the state of a complex system. To solve the problem of aggregation of initial data authors used the fuzzy cluster analysis, namely the fuzzy k-means method. The results allow to formalize linguistic variables, which are characterized by the term-sets and definition range. The numerical results were approximated by analytical membership functions. The solution of the first task allows to generate a set of possible fuzzy reference situations. Each situation is characterized by the reference informational granule, which contains information about formalized linguistic variables. The second problem was solved by using the method of fuzzy logic in the MATLAB environment. In this test case, the search of the situation in which the IT-company is located was performed. At this stage, the current situation belongs to comparison with each reference situation. In this way, authors determined the most similar reference situation to the current situation. An analysis of the resulting situation allows to argue the state of the IT company. The solution of the second task allowed to establish assessment of IT company state. The theoretical and practical results can improve the efficiency of complex system management.

Keywords: complex system management, condition assessment, fuzzy cluster analysis, fuzzy situational approach, reference situations, informational granule

I Introduction

Information technologies are rapidly evolving with each passing day and in turn there is a growing need for using of certain software products in various fields of activity. Many modern enterprises sooner or later face the situation, when to improve the functioning of the organization it is necessary to implement specialized software for automation, data processing, etc. In order to implement this, it is important to determine how the company intends to obtain the necessary software. In this situation, there are 3 common options. The first is to create a software product by themselves, but it is possible only if there is an IT department at the enterprise, whose employees posess the necessary skills and will be able to create a product that meets the requirements of the enterprise. The second option is to acquire a license for an existing software product, but it is quite difficult to find a product that is appropriate for the company and satisfies all the needs. If the first and second options are not suitable, the company chooses the third. IT companies come to the rescue here.

The rapid development of information technology has led to the emergence of a large number of IT companies engaged in custom software development. As already mentioned, the need for software in today's modern world is very great, so we can say that an IT company is a very promising and profitable business.

Due to the fact that there are many such companies and their number is only growing, there is a huge competition between them. In order for this business to be

successful and profitable it is necessary to perform a huge amount of work, to execute orders qualitatively and to keep control of the state of the company at different intervals of time.

II Analytical review of literature

The group of researchers propose a technology for assessing the state of complex systems. It was decided to use the methods of fuzzy logic to solve the problem. The solution consists of two main stages, namely, aggregation of the initial data and assessment of the state of a complex system.

The solution to the problem of aggregating information is to adjust the source data for use, that is, leading to fuzziness. In order to better understand this problem, the works of A. Genkin “New Information Technology for Danish Analysis” and Borisov A.I., Aleksev A.V., Krumberg O.A. “Models adopted on the basis of linguistic knowledge” turned out to be very useful.

The second task is to identify a fuzzy situation that characterizes the state of a complex system. Having studied all possible methods for solving this problem using the work of A.N. Melikhov's “Situation Systems with Fuzzy Logic”, it was decided to use the Mamdani algorithm in fuzzy inference systems.

As an object of research, and from a directly complex system, an IT company was chosen. In order to get acquainted with the structure of the enterprise, the intricacies of functioning and the attributes used as input data, an analysis of many sources was carried out, the most useful work was A. Pogorilogo “Basic Element of Effective Video IT”.

All calculations were carried out with MATLAB. All methods used in the work are present in this environment. In order to familiarize yourself with the procedure for using these methods, the work of A. Leonenkov "Something model in MATLAB and fuzzyTECH." is useful.

The results of the literature review showed that these problems are completely underdeveloped and very poorly covered.

III Object, subject matter and methods of research

Description of the object of study. The subject of the study is the IT company Z, whose head office is located in Kiev. The company has offices in other major cities of Ukraine, namely: Kharkiv, Lviv, Odessa and Dnipro, as well as abroad in Budapest and Krakow. The company was established in 2007, but is expanding very rapidly and opening new branches outside Ukraine. At present, the company employs about 1000 employees with various programming technologies.

The company is characterized by the fact that it develops custom software for foreign companies. The company operates on the B2B (Business to Business.) Model, that is, produces services and products not for the end-user, but for other business companies. Services offered by developers - development, testing, support and support of custom software and business applications, creation of dedicated centers of development, testing and quality control of software, as well as IT consulting taking into account industry specific business (finance, insurance, medicine, biotechnology, energy).

Formulation of the problem. The group of researchers formulated the statement problem to assess the state of a complex system in terms of situational control in a fuzzy environment.

The condition of the control object can be assessed by the values of attributes – the distinguishing features of the object. The power of the set of features is determined by the goals of object management and the features of the control system. A set of values of features that describe the state of a control object and the environment at a particular point in time, will be called as a situation in current work.

Note that when describing the values of the features can be obtained unjustifiably large number of situations. In this case, it is advisable to aggregate the information.

In the work it is proposed to use expert knowledge to construct a decisive table. Naturally, when describing situations, the expert's attention will focus on the typical typical situations that arise when managing the object. The number of typical or reference situations is significantly less than the total number of situations.

The set of reference situations describe the possible states of the object fairly fully, taking into account management features. However, it is impossible to take into account all the features of management. This leads to the need to use the notion of a fuzzy situation.

Let the authors give a formal definition of "fuzzy situation". Let Y – be a set of features which values describe the state of the control object. Each attribute Y_i is described by a linguistic variable $< Y_i, T_i, D_i >$, where $T_i = \{T_{1i}, \dots, T_{mi}\}$ – is a term-set of a linguistic variable Y_i, mi – the number of values of the trait; D_i – base set of attribute Y_i.

The number of possible situations on business – is greater, and the number of decisions taken is much less. As there are many more situations of casualty and leather, you can set up one of the most common types, then the task of managing, roughly speaking, needs to be reduced to the next level, if necessary. Thus, the problem of identification is presented in the vision of two tasks. The first one is agregation of the input of information and the second – identification of the situation, which describe the current state of the IT – company.

Approaches to solving the problem. The research problem can be solved using one of the following approaches:

– situational approach;

– system approach.

The group of researchers decided to consider these approaches to solving the research problem in more detail.

The systems approach views the organization as an open system consisting of several interconnected subsystems. Systems theory helps the manager understand the relationship between the individual parts of the organization, between the organization and the environment. The main drawback - systems theory does not identify the main variables that affect the control function, does not say about the impact of the environment on the performance of the organization.

The situational approach broadened the practical application of systems theory by identifying the major internal and external variables that affect an organization. He argues that management techniques and concepts should be appropriate to the particular situation. The main disadvantage of this approach is that only those factors that are most relevant to the organization and its leader can be taken into account.

Considering these approaches, it was concluded that the application of a systematic approach is ineffective to solve our research problem. Therefore, the formulation of the research problem was formulated in terms of situational management.

Thus, the solution to the problem of assessing the status of the IT company consists of two stages: aggregation of information and assessment of the state of the company.

The problem of aggregation is proposed to be solved with the use of fuzzy cluster analysis to make the input data unclear and to describe linguistic variables. There are two basic clustering methods that allow you to simultaneously split the output into classes and represent the resulting classes as fuzzy sets, namely:

– method of fuzzy k-means clustering;
– Gustavson-Kessel method.

From these algorithms, it is proposed to use the fuzzy k – mean clustering method, as it is fairly accurate, easy to implement, and reliable. In the second method, not all of the above items are executed.

The solution to the second problem (state estimation) is proposed to be obtained using fuzzy logic. Among the possible methods are:

– Mamdani algorithm;
– Fuzzy inclusion of situations.

It was decided to evaluate the state of the company using the algorithm of Mamdani, since this algorithm is implemented in the Matlab package, unlike other, which will allow to conduct test accounts and compare them with those obtained in the developed software solution.

An algorithm for solving the problem of assessing the financial condition of an IT company. Based on the formulation of the task, the assessment of the status of the IT company is considered in terms of situational management in a fuzzy environment. Thus, the state of the company can be judged by the values of attributes – the distinguishing features of the object. The number of features that characterize the status of the company is determined by the goals of object management and features of the management system. A set of feature values that describe the state of a control object and the environment at a particular point in time is called a situation. In other words, the state of the company will be presented in the form of a situation of many formed reference situations, which most accurately characterizes the state of the IT enterprise.

In order to solve the problem of the research, an algorithm of a sequence of actions has been formed, which must be carried out in order to adequately assess the current state of the company. The main steps are:

1 Generation of input data. At this stage, all management goals and features of the IT company should be analyzed. As a result, a set of features will be generated, which will be presented in the form of the current situation in the IT company.

2 Normalization of the output data. All the features that describe the status of the company have different dimensions. During the assessment, there will be a need to compare these traits. Thus, in order to make it possible to compare the features it is necessary to bring them to a single scale. As a result of rationing, all features should be represented in the range [0; 1].

3 Data aggregation. The task of the study involves the construction of a fairly complex mathematical model. In order to reduce the scope of the problem and to simplify

the procedure of state estimation, it is advisable to aggregate the input features, that is, to describe them as linguistic variables. This will create many reference situations and greatly simplify the IT company assessment process.

4 Formation of set of the reference situations. At this stage, the formation of all possible states in which the company may be located. The number of situations will depend on the number of input features and the results of information aggregation.

5 Formation of the current situation. Based on the values of the characteristics that characterize the status of the company, the current situation is formed, which describes the current state of affairs in the company. Aggregation results will be used to shape the current situation.

6 Identification of the most similar reference situation with the current one. The last stage of the process of assessing the condition of the company, which involves finding the most similar situation from the generated list of reference, with the current situation. The result will be one situation that will most accurately characterize the status of the company. This situation is considered in more detail and formed the argumentation of the state of the IT company in which it is currently located.

Rationg of the input data. The attributes that characterize the status of the company have different dimensions. In order to be able to compare these features it is necessary to bring them to a dimensionless appearance. Thus, the intervals considered should be reduced to a single scale. To qualitatively assess the status of the company, we should focus on a method that allows less fuzzy term sets of linguistic variables to be obtained. After analyzing the methods of valuation, it was decided to use sigmatic data normalization:

The method of sigmatic rationing has the advantage over most other methods, because it is more reliable to focus on normalization not on extreme values, but on typical, that is, statistical characteristics of data, such as mean and variance. Sigmatic normalization allows to find a natural way out of this situation and at the same time all values $x_i^* \in [0; 1]$. Sigmatic normalization is carried out by the formula (1).

$$x_i^* = f\left(\frac{x_i - \overline{x}}{\sigma}\right), \quad (1)$$

$$where\ \overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (2)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n}}; \quad (3)$$

$$f(a) = \frac{1}{1 + \exp\{-a\}} \quad (4)$$

Input data aggregation. Aggregation of information refers to the concentration of individual flows of information in the information pellet - the only aggregate, which gives the opportunity to get a general picture of the situation in the system. The information pellet is a linguistic variable.

As previously defined, the formation of the information pellet will be carried out using one of the most common fuzzy clustering k-means clustering algorithms. One of the

main disadvantages of this algorithm is that it is necessary to specify in advance the number of clusters that will be clustered. But this is not a problem for solving the research problem, since within the given task, the number of clusters k is determined in advance. The number of clusters in this task will depend on the number of terms of each linguistic variable.

As a result of the algorithm, the following data will be obtained: V_{ip} – Cluster centers for each attribute p, F_p – a matrix of the affiliation of each element to all possible clusters.

To solve the problem of information aggregation, the following solution algorithm was constructed:

1 In the first stage of the algorithm, the input data is specified. In our case it is:

– input attributes $X = \{x_1, x_2, \dots, x_p\}$;

– The number of clusters (terms of the linguistic variable) $k = \overline{1, M}$;

– exponential weight $m = [1; \infty)$ (by default $m = 2$).

Each element will be closer to one of the points. Not all of them will aspire to one center of gravity, so several clusters are formed. We now have k clusters, and each element is a member of one of them;

2 Then it is necessary fill the membership matrix F_p randomly, which is sized $M \times c$ of fuzzy partitioning. At each iteration, the membership matrix will change until the aggregation of information is completed, so the initial filling of the matrix does not require any knowledge. It is only important that the generated matrix satisfies the condition (5):

$$\sum_{i=1}^{c} \mu_{ki} = 1, k = \overline{1, M}. \quad (5)$$

That is, the degree of belonging of each element to a certain set cannot be more than 1.

3 In the next step, it is necessary to define the cluster centers by the degree of membership by the formula (6).

$$V_i = \frac{\sum_{k=1}^{M} \mu_{ki}^m x_k}{\sum_{k=1}^{M} \mu_{ki}^m}, i = \overline{1, c} \quad (6)$$

Each term of a linguistic variable is referred to as a center, that is, a value that achieves the maximum degree of certainty. There will be one center for each term.

4 In this step, the distances between the new cluster centers and the data points are calculated. Finding the distance between points is done using the Euclid distance by the formula (7). This formula is the most widespread in cluster analysis.

$$D_{ki} = \sqrt{\|x_k - V_i\|^2}, k = \overline{1, M}, i = \overline{1, c} \quad (7)$$

Knowledge of distances from points to clusters allows to determine the value of belonging of elements to clusters.

5 It is now necessary to list the degree of affiliation of the objects to the cluster. This is done using the formula (8). This way, the values in tha matrix F_p are changing.

$$\mu_{ki} = \frac{1}{\sum_{j=1}^{c} \left(\frac{D_{ki}}{D_{kj}}\right)^{2/m-1}}, k = \overline{1,M}, i = \overline{1,c} \quad (8)$$

6 Steps 3 to 5 are repeated until the cluster centers have stopped changing. Thus, when the cluster centers cease to change, the execution of the algorithm ends. The cluster centers V_i and membership matrix D_{ki} obtained as a result of the last iteration are finite. These results will be used in the future. Namely, the cluster centers and the membership matrix of each trait will be used to form a set of reference situations, the current situation and to make the input traits indistinct. Using the value of the membership matrix, it is possible to graphically represent the membership functions of the elements of each attribute in all possible terms.

Formation of the set of reference situations. A set of values of characteristics that describe the state of an IT company at a certain point in time, let's call it a situation. If p – the number of attributes, m_i – the number of attribute values $y_i \in Y(i \in J = \{1,2,\dots,p\})$ then the number of possible situations in the company will not exceed than $m_1 \times m_2 \times \dots \times m_p$. Having formed the set of all possible situations, their number will prove unreasonably large. In order to solve this problem, information was aggregated.

All possible states of a company can be described by a set of so-called, reference situations. Each is a set of linguistic meanings of features. The number of reference situations is much less than the number of all possible situations and fairly accurately describes the state of the IT company and will not exceed $t_1 \times t_2 \times \dots \times t_p$, where t_i – the number of attribute terms $y_i \in Y(i \in J = \{1,2,\dots,p\})$.

For example, the condition of an IT company is characterized by two attributes x_1 and x_2. Definition range of x_1 is between 0 and 15 and x_2 betweet 0 and 50. This way, the maximum number of possible situtions is $15 \times 50 = 750$. Two linguistic variables $\{x_1, T_1, D_1\}$ and $\{x_2, T_2, D_2\}$were described by aggregating the data, where $T_1 = T_2 = \{$"few","$enough$","$many$"$\}$, $D_1 = [0;15]$, $D_2 = [0;50]$. Thus, it becomes possible to form a set of reference situations. Their number will be equal $3 \times 3 = 9$ and they will be formed as follows:

$$S_1 = \{\ll "t_{11}" > / x_1 > / \dots / \ll "t_{p1}" > / x_{\mathrm{p}} >.$$
$$S_2 = \{\ll "t_{11}" > / x_1 > / \dots / \ll "t_{p2}" > / x_2 >.$$
$$\dots$$
$$S_s = \{\ll "t_{12}" > / x_1 > / \dots / \ll "t_{pk}" > / x_2 >.$$
$$\dots$$
$$S_{\mathrm{r}} = \{\ll "t_{1k}" > / x_1 > / \dots / \ll "t_{pk}" > / x_2 >.$$

Formation of the current state of the company. In order to get an assessment of the status of an IT company, it is necessary to determine what the situation in the set of benchmarks is able to most accurately characterize the current state of affairs in the

company. To do this, it is important to form the current situation S_0 and compare it with each reference situation. In order to shape the current situation of the company, it is necessary to refer to the data obtained as a result of the argumentation, the membership matrix F_p and to determine for each attribute with what probability and to which term the current meaning of the attribute belongs. Based on the above current situation S_0 can be represented as follows:

$$S_0 = \{\ll \max(\mu_1(x_1), \mu_2(x_1), \dots, \mu_k(x_1)/"t_{1k}" >/x_1 >, \dots, \\ \ll \max(\mu_1(x_p), \mu_2(x_p), \dots, \mu_k(x_p)/"t_{pk}" >/x_p >\}, \quad (9)$$

where k – the number of terms/clusters,

p – the number of attributes,

$\mu_k(x_p)$ – the degree of belonging of attribute x_p to the k–th term,

t_{pk} – the name of the term with the highest degree of certainty.

Identification of the most similar reference situation with the current one (Mamdani algorithm). One possible way to find the most similar situation from the set of benchmarks to the current situation is Mamdani's Fuzzy Algorithm. This algorithm consists of 6 steps, described below:

1 Forming a rule base. The rule base is a set of rules. The input variables are the linguistic attribute variables $x_1, x_2, \dots, x_p$. Output variable – Situation, which is the conclusion. Thus, as a result of the algorithm, we have to get one of the possible situations. The number of rules in the database should match the number of possible reference situations. The rule base for the research task will be as follows:

2

Rule 1: If x_1 «t_{11}» AND x_2 «t_{21}» AND … AND x_p «t_{p1}»» THEN Situation = S_1

Rule 2: If x_1 «t_{11}» AND x_2 «t_{21}» AND … AND x_p «t_{p2}»» THEN Situation = S_2

…

Rule r: If x_1 «t_{1k}» AND x_2 «t_{2k}» AND … AND x_p «t_{pk}»» THEN Situation = S_r

3 Fuzzification of input variables. At this stage, the input features are made fuzzy. An input database of rules and an array of input data are input. The purpose of this step is to get truth values for all the sub-rules from the rule base.

4 For each rule, the degree of belonging of the input value to a particular term set is determined. The minimum value is selected from the specified values using the formula (10).

$$c_j = min\{\mu_j(x_1), \dots, \mu_j(x_p)\}, \overline{j = 1, r} \quad (10)$$

For this purpose can be used matrixes of the resulting clustering, or substituting the original values of the features in the corresponding functions obtained by the approximation.

5 At this point, truncated sets are searched. The number of truncated sets must match the number of rules. All truncated sets were defined by the formula (11).

$$\mu_i^*(y) = mi\,n\{c_i, \mu_j(S)\}, \overline{i = 1, r} \quad (11)$$

6 Next, the union of the original set was constructed. It is the union of all truncated sets and is defined by the formula (12).

$$\mu_i^{**} = max\{\mu_i^*(S)\} \quad (12)$$

7 In the last step, a clear value of the original variable was defined, ie the situation number describes the status of the company. For the dephasification, it was decided to use the maximum center method. In the method of the center of maxima is the arithmetic mean of the elements of the universal set with maximum degrees of accessories, the formula (13).

$$y = \frac{\sum_{x_j \in G} x_j}{|G|}, \quad (13)$$

where G – the set of items with the maximum degree of belonging;
$\sum_{x_j \in G} x_j$ – the sum of the elements of the set G;
$|G|$ – the power of the set G.

IV RESULTS

A test case was considered, in which 24 employees are currently employed in the company. For the projects under development, the company received from the customers 4200 USD, while the implementation of projects spent 950 USD. In the process of development 37 units were involved equipment.

This way:

$$x_1 = 24;$$
$$x_2 = 4200;$$
$$x_3 = 950;$$
$$x_4 = 37.$$

The vector characterizing the current state of the company will be as follows:

$$\overline{X} = \{x_1, x_2, x_3, x_4\} = \{24, 4200, 950, 37\}.$$

We use the results of data normalization and write the values of the features in dimensionless form:

$$x_1^{'} = 0{,}7275;$$
$$x_2^{'} = 0{,}3165;$$
$$x_3^{'} = 0{,}3359;$$
$$x_4^{'} = 0{,}7139;$$

Next, based on the input and the results of the data preparation (clustering and approximation) it became possible to form the current situation S_0, which characterizes the current state of the company. For each feature, the degree of belonging to each cluster is

determined and the maximum value is selected. So the current situation S_0 was formed as follows: $S_r, r = \overline{1,81}$

$$S_0 = \{\ll 0{,}98/many >/x_1 >, \ll 0{,}8364/few >/x_2 >, \ll 0{,}7326/many >/x_3 >, \ll 0{,}9538/many >/x_4 >\}.$$

Next, it is necessary to determine which situation is from the set of reference situations $S_r, r = \overline{1,81}$, is the most similar with the current situation S_0. For this purpose, it was decided to use the algorithm of fuzzy inference of Mamdani. The fuzzy k-means clustering method made it possible to represent term sets in the form of membership functions. In other words, the phasification of the input variables was performed, which is a prerequisite for applying the Mamdani algorithm. As an unput data, there are attributes $x_1^{'}, x_2^{'}, x_3^{'}, x_4^{'}$, which characterize the condition of the company and they are already reduced to a dimensionless form. The output must be a situation number from the list of reference situations most similar to the current situation. Based on the conditions of the problem, a rule base for the Mamdani algorithm was formed:

Rule 1: IF x_1 «few» AND x_2 «few» AND x_3 «few» AND x_4 «few» THEN Situation = S_1

Rule 2: IF x_1 «few» AND x_2 «few» AND x_3 «few» AND x_4 «enough» THEN Situation = S_2

Rule 3: IF x_1 «few» AND x_2 «few» AND x_3 «few» AND x_4 «many» THEN Situation = S_3

Rule 4: IF x_1 «few» AND x_2 «few» AND x_3 «enough» AND x_4 «few» THEN Situation = S_4

Rule 5: IF x_1 «few» AND x_2 «few» AND x_3 «enough» AND x_4 «enough» THEN Situation = S_5

…

Rule 77: IF x_1 «many» AND x_2 «many» AND x_3 «enough» AND x_4 «enough» THEN Situation = S_{77}

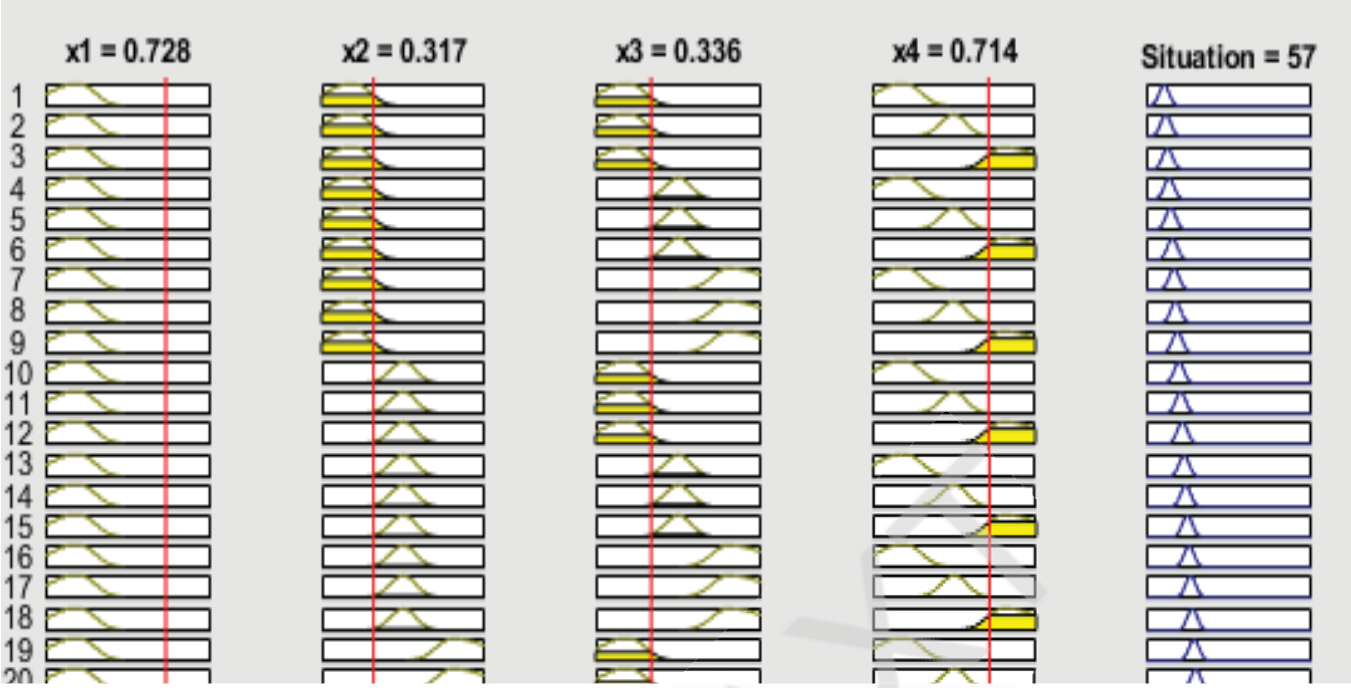
Rule 78: IF x_1 «many» AND x_2 «many» AND x_3 «enough» AND x_4 «many» THEN Situation = S_{78}

Rule 79: IF x_1 «many» AND x_2 «many» AND x_3 «many» AND x_4 «few» THEN Situation = S_{79}

Rule 80: IF x_1 «many» AND x_2 «many» AND x_3 «many» AND x_4 «enough» THEN Situation = S_{80}

Rule 81: IF x_1 «many» AND x_2 «many» AND x_3 «many» AND x_4 «many» THEN Situation = S_{81}

Thus, a rule base consisting of 81 rules was formed. Now you are ready to run the algorithm. The initial data was specified according to the conditions of the test example and the following result was obtained (pic. 3.2):



Picture 3.2 – The result of the implementation of the Mamdani algorithm

The results are presented in the table 3.7.

Table 3.7 – Obtained results

x_1	x_2	x_3	x_4	S
0.728	0.317	0.336	0.714	57

Thus, it can be concluded that among the set of reference situations one, most similar situation to the current situation S_0 was found. The situation number is $r = 57$. This situation was found in the list of reference situations and is written as follows:

$$S_{57} = \{\ll 0{,}992/many >/x_1 >, \ll 0{,}98/few >/x_2 >, \ll 0{,}991/few >/x_3 >, \ll 0{,}998/many >/x_4 >\}.$$

Further, this result is considered in more detail and reasoned readings of the current state of the IT company are formed.

It is worth to notice that when considering a real task, the number of input features, characterizing the state of the company will be significantly larger than in this test example. This example demonstrates the efficiency of the method of assessing the condition of complex objects cited by the authors. The solution will be relevant for any number of input parameters. The only nuance is that when solving a task of a rather large size, powerful computing resources may be needed.

V Conclusions

As part of the work, the problem of assessing the state of the enterprise (on the example of an IT company) was considered. The problem is presented in the form of two tasks, namely: aggregation of input information and identification of the state of a complex system.

Having identified the problem, the formulation of the problem was formulated and the possible methods for its solution were considered. The most feasible solutions were chosen among the possible methods.

A fuzzy k-means method was used to solve the problem of input data aggregation. Some numerical calculations were made and a test case was calculated. The numerical result obtained was approximated by the analytic membership functions. The solution of the first problem allowed to form many fuzzy reference situations. Each situation in this set is characterized by an information pellet.

The second problem was solved using the fuzzy logic method. A test case was calculated. During the calculations, using the fuzzy logic method, the current situation at the enterprise was compared with the reference situations. As a result, it was determined which of the reference situations is closest to the current situation. This made it possible to assess the status of the IT company.

The obtained theoretical and practical results allow to increase the efficiency of the process of managing a complex system.

VI List of references

1. Borisov A.I., Alekseev A.V., Krumberg O.A. Modeli prinyatiya reshenij na osnove lingvisticheskoj peremennoj [Decision-making models based on linguistic variable]. Riga; Zinatne. 1982. S. 142-150.

2. Goloskokov A.E, Drach T.A., Shapoval S.E.. Nechetkaya identifikaciya dinamicheskix obektov [Fuzzy identification of dynamic objects]. Visnik NTU «XPI». Seriya: Sistemnij analiz, upravlinnya ta informacijni texnologiï. – Xarkiv : NTU «XPI», 2017. – № 42 (948). – Bibliogr.: 5 nazv. – ISSN 2079 0023.

3. Melikhov A.N., Bershtejn L.S., Korovin S.Ya. Situacionnye sovetuyushhie sistemy s nechetkoj logikoj [Fuzzy logic situational advisory systems]. Moskva: Fizmatlit., 1990. S. 44-59.

4. Melixov A.N., Bershtejn L.S. Formirovanie klassov rasplyvchatyx situacij specializirovannym ustrojstvom ochuvstvlennogo robota. [Formation of classes of vague situations by a specialized device of a sensible robot]. Moskva: Fizmatlit, texn. kibernetika, 1983. S. 88-110.

5. Plyshevskiy B. P. Finansovoe polozhenie: novye tendentsii [Financial situation: new trends]. Finansy [Finances]. Moscow, "Knizhnaya redaktsiya finansy" Publ., 2003, no 2, pp. 18–20.

6. Rotshteyn A. P. Intellektual'nye tekhnologii identifikatsii: nechetkie mnozhestva, geneticheskie algoritmy, neyronnye seti [Intellectual identification technologies: fuzzy sets, genetic algorithms, neural networks]. Vinnitsa, Universum-Vinnytsya Publ., 1999. 320 p.

7. Orlov A. I. Nechislovaya statistika [Non-numeric statistics]. Moscow, MZ-Press Publ., 2004. 513 p.

8. Samarskiy A. A., Mikhaylov A. P. Matematicheskoe modelirovanie. Idei. Metody. Primery [Math modeling. Ideas. Methods. Examples]. 2-e izd. Moscow, Fizmatlit Publ., 2001. 320 p.

9. Matviychuk A. V., Smetanyuk O. A. Diagnostirovanie finansovogo sostoyaniya predpriyatiya s primeneniem instrumentariya nechetkoy logiki [Diagnosing the financial condition of an enterprise using fuzzy logic tools]. Finansy Ukrayiny [Finance of

Ukraine]. Kiev, SAI "Academy of Financial Management" Publ., 2007, no 12, pp. 115–128.

10. Shtovba S. D. Vvedenie v teoriyu nechetkikh mnozhestv i nechetkuyu logiku [Introduction to the theory of fuzzy sets and fuzzy logic]. Available at: http://matlab.exponenta.ru/fuzzylogic/book1/index.php (accessed 20.01.2013).

11. Matviychuk A. V. Analiz ta prohnozuvannya rozvytku finansovo-ekonomichnykh system iz vykorystannyam teoriyi nechitkoyi lohiky [Analysis and forecasting of the development of financial and economic systems using the theory of fuzzy logic]. Kiev, Tsentr navchal'noyi literatury Publ., 2005. 183 p.

12. Borisov V. V., Kruglov V. V., Fedulov A. S. Nechetkie modeli i seti [Fuzzy models and networks]. 2-e izd. Moscow, Goryachaya liniya–Telekom Publ., 2012. 284 p.Recieved 28.05.2019

THE DEVELOPMENT OF THE TOOL FOR REAL-TIME NOTIFYING THE PEOPLE ABOUT LEVEL OF AIR POLUTION IN RECREATION ZONES

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Abstract.*The main goal of our research is to confirm the hypothesis of a relatively high level of air pollution in the city Kramatorsk and to create a tool for notifying the people of this information. This work demonstrate why the task of creating a convenient, accessible, functional, accurate interactive map of the state of environmental pollution in recreational areas of the city, which could allow residents to choose the least polluted recreation areas at the current time, is relevant.*

Keywords: *Interactive map, Air pollution, OpenStreetMap, API, Recreation zone, PM, Substance, Monitoring*

Introduction

The current environmental situation in Ukraine can be described as the maximum crisis, which was formed over a long period due to the neglect of objective laws of development and reconstruction of the natural resource complex of Ukraine. There were structural deformations of the national economy, in which preference was given to the development of raw-mining, the most environmentally dangerous industries in Ukraine. The level of contamination with various substances exceeds the norm not only in the so-called "work zones", but also in residential areas and recreational areas. Cities in industrial zones of Ukraine, in particular in the Eastern part of Ukraine, are most at risk. Recreational areas are created in order to allow people to relax and reduce the load received by the human body from the urbanized atmosphere of cities. But practice shows that the situation in recreation areas is also not satisfactory, and in some cases even more dangerous than in other places of the settlement. The most annoying thing is that most people do not even suspect that these places are as dangerous as, for example, work areas.