Correction of the Knowledge Database of Fuzzy Decision Support System with Variable Structure of the Input Data

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Abstract: *The review of the existing approaches and algorithms for designing DSS based on fuzzy logic in case of changing the structure of the vector of the input data is considered in the paper. There was presented the own approach, which lies in correction (editing) the rules of fuzzy knowledge bases at different number of input coordinates of the system. Simulation results confirm the effectiveness and appropriateness of use of the algorithms of editing the rules of fuzzy knowledge bases in the process of DSS designing for management decision-making, particularly in solving problems of transport logistics.*

Keywords**:** DSS, fuzzy logic, transport, logistics.

1. INTRODUCTION

Information and software systems play an important role in solving control problems, as they are destined for analysis, planning and supporting of processes of making technical and commercial decisions.

DSS for solving different-type problems help decision-makers (DM) to form and use appropriate amounts of a prior and current data, models, algorithms and criteria of effective decision-making [1] in automatic and interactive modes.

Fuzzy DSS with a variable structure of the vector of input data is a system the number of input characteristics of which can vary in the process of decision-making by DM [2].

DSS are widely used in economics, enterprise organization, medicine, agriculture, technical diagnostics and others. One of the important areas of DSS appliance is transport logistics [1].

2. GENERAL PROBLEM STATEMENT

For analysis and creation of alternative decisions in DSS different theoretical approaches are used, including intelligent data analysis, simulation and fuzzy modeling, genetic algorithms, neural networks, decision-making theory, theory of fuzzy sets and fuzzy logic, etc. [3].

Recently, the use of fuzzy logic in control systems and DSS has gained wide acceptance [3].

The study of fuzzy logic is concerned with a need to develop intelligent systems that can interact with a human-operator, taking from him verbal (fuzzy) information [4].

Among the new possibilities that have appeared in scientific and technical researches by virtue of the theory of fuzzy sets [2], should be noted:

– the possibility of creating artificial intelligence similar to human intelligence and its appliance to machines and robotics;
– creating computerized systems that are taken to programming with the help of natural language using fuzzy concepts;
– use of information of any granulation degree in the tasks of modeling, control, optimization and diagnostics.

Application of the theory of fuzzy sets and fuzzy logic in the process of designing DSS allows solving problems on an intellectual level, using herewith the knowledge database of experts [4].

The process of making effective decisions consists in choosing the best alternative variant among the existing by a certain system of criteria and advantages and by a set of valuation options (input coordinates of the system) [5].

One of the problems of synthesis of DSS based on fuzzy logic derivation is difficulty in making decisions at the variable structure of input data of the system (at different dimension of the vector of input coordinates) [2]. This is connected with the need to develop effective approaches as for correction of the fuzzy knowledge databases (FKD). The necessity of proper adjustment or circumvention of the rules with regard to incoming signals that are at the choice of DM excluded from the vector of the input coordinates occurs at a particular application of DSS in the interactive mode. In such interactive modes DM can reduce the dimension of the vector of the input coordinates of DSS, eliminating the least important for DM input signals, which are no longer participating in the process of decision-making.

3. THE REVIEW OF RECENT RESEARCHES AND PUBLICATIONS

Today there exist a lot of publications on the research of DSS based on the fuzzy logic [5, 6, 7], which examine methods of the theory of fuzzy sets for modeling, analysis and synthesis of intelligent systems. Researches, which are conducted in different countries, have proved that for many subjects to management, parameters of which change in the process of operation, it is appropriate to use fuzzy computerized automatic control systems [8, 9, 10].

In fuzzy modeling it is the most commonly to use Mamdani algorithm, whereby antecedents and consequent of the rules of the fuzzy knowledge databases are formed on the basis of linguistic terms that are indicated by fuzzy sets of such types as “Low”, “Average”, “High”, etc. The fuzzy rules of such type were proposed by L. Zade in the paper [11], upon which Mamdani and Assilian developed the first fuzzy controller [12]. The fuzzy Mamdani-type models are transparent, unlike models of “black box” type, their structure is interpreted in terms easily understood not only by developers, but also customers – doctors, economists, managers. Transparency of the fuzzy Mamdani-type models is one of the main advantages that allow competing successfully with other methods [13].

To improve accuracy of modeling results and effectiveness of making decisions the fuzzy model is previously examined, in other words its parameters are iteratively changed to minimize the results deflection of logical derivation from experimental data. They adjust both the weight of the rules and membership functions (MF) of the fuzzy linguistic terms. Learning procedure of the fuzzy Mamdani-type model presents a nonlinear optimization problem, within a framework of which the main attention is paid to achieving the maximum accuracy of learning of the fuzzy DSS [13].

For different DM the part of input coordinates can be not important according to their own priorities. For example, if a synthesized DSS operates effectively at 12 input signals $(N = 12)$, in some cases a specific DM may be interested in and he can only ask, for example, just 8 input signals $(N_r = 8)$, and other 4 input signals $(N_{NI} = 4)$ DM excludes from consideration as they are not essential (not important) for him $N_r + N_{NI} = N$. That is the dimension of the vector of the input coordinates reduces from 12 to 8. Among the known approaches to the correction in such cases of the databases of the fuzzy DSS is the use of a weighable coefficient for the fuzzy rules.

A change of weighable coefficients for the relevant rules of the fuzzy knowledge databases allows reducing the influence of the input parameters, which due to DM choice in some cases can't participate in the process of making decisions, on the result of work of the system. However, in this case the necessity of re-configuration of corresponding coefficients at each change of the structure of the input data appears [10, 14, 15].

Another example of appliance of optimization methods and correction of fuzzy rules databases is systems with adaptive fuzzy management for automatic control and regulation of temperature, in which the rules can be changed in the process of receiving fuzzy results evaluation [16].

4. THE STRUCTURE OF FUZZY DSS

In the article [17] a review of the existing tasks of transport logistics was conducted and a method of solving one of the tasks was presented, namely, evaluation of the quality of cargo delivery with the help of DSS on the bases of fuzzy logical interference of Mamdani-type. The analysis of literary sources [18, 19] shows that among the input factors (coordinates, signals) we can separate 19 that are the most important $(N = 19)$. For fuzzy DSS of such type (with 19 input coordinates) particularly actual is a problem of automatic adjustment of fuzzy rules databases in situations when a specific DM is interested in real N_r input coordinates, herewith $N_r < N$. Hereinafter we will in more detail way observe an approach proposed by authors that allows with the help of DSS of aforementioned class providing a creation of optimal decisions (according to the content of previously selected criteria) by correction of the rules databases at apriori uncertainty of input information, that is $N_r < N$.

For illustration of the approach proposed by authors as an example we will observe fuzzy DSS that has 5 input parameters x_i, $i = 1,...,5; N = 5$, particularly x_1 – delivery price; x_2 – timeliness of the delivery; x_3 – convenience of maintenance in the process of delivery; x_4 – keeping by the number of cargo; x_5 – keeping the quality of cargo. Output variable is the indicator of the quality of cargo delivery F.

As a result of structuring of the input data as a part of the two-level DSS 3 fuzzy subsystems were formed that implement the following dependences [17]:

– for the first hierarchical level of fuzzy DSS:

$$y_1 = f_1(x_1, x_2, x_3);$$

$$y_2 = f_1(x_4, x_5);$$

– for the second hierarchical level of fuzzy DSS:

$$F = f_3(y_1, y_2).$$

The structure of the hierarchical fuzzy DSS that consists of 5 input linguistic variables $\{x_1, x_2, x_3, x_4, x_5\}$, 3 knowledge databases with fuzzy rules $\{f_1, f_2, f_3\}$ and one output linguistic variable F, is presented in the Fig. 1.

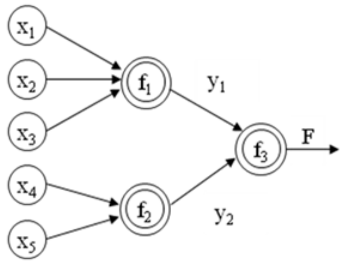

Fig. 1 – Hierarchical structure of fuzzy DSS.

In the process of structuring the input variables are combined by common characteristics that are principal (important) for a particular fuzzy subsystem. Such hierarchical approach allows reducing the amount of fuzzy rules of the knowledge database and thus increasing the sensitivity of the system to the operations of the input variables (factors) [1, 2, 20].

While describing the linguistic variables for DSS that was presented in the Fig. 1, a diapason of variation values, the number of terms and the form of the MF (triangular) were defined. Corresponding the structure of DSS (Fig. 1) the authors has created three fuzzy knowledge databases with fuzzy rules of production of “IF – THEN” type, the first one of which $y_1 = f_1(x_1, x_2, x_3)$ will be further observed in more detail.

In the table 1 there is presented a set of rules from the knowledge database of the first subsystem $y_1 = f_1(x_1, x_2, x_3)$ of fuzzy DSS. Herewith for evaluation of all input variables $\{x_1, x_2, x_3, x_4, x_5\}$ in threes linguistic terms are used (L – “low”, M – “medium”, H – “high”), and for evaluation of output variable – 5 corresponding terms (L – “low”, M – “medium”, MH - “higher than mean”, H – “high”).

The project of hierarchically organized DSS for the evaluation of the quality of cargo delivery, whose structure is presented in Fig. 1, can be synthesized, for example, in computing environment MatLab or in a computing environment FuzzyTECH [21].

Table 1. The rules database of the first fuzzy subsystem $y_1 = f_1(x_1, x_2, x_3)$

№ of the rule	x_1	x_2	x_3	y_1
1	L	L	L	L
2	L	L	M	LM
3	L	L	H	M
4	L	M	L	LM
5	L	M	M	M
6	L	M	H	M
7	L	H	L	M
8	L	H	M	M
9	L	H	H	MH
10	M	L	L	L
11	M	L	M	LM
12	M	L	H	M
13	M	M	L	LM
14	M	M	M	M
15	M	M	H	MH
16	M	H	L	M
17	M	H	M	MH
18	M	H	H	H
19	H	L	L	LM
20	H	L	M	LM
21	H	L	H	M
22	H	M	L	M
23	H	M	M	MH
24	H	M	H	H
25	H	H	L	M
26	H	H	M	MH
27	H	H	H	H

5. THE ALGORYTHM OF CORRECTION OF THE KNOWLEDGE DATABASES OF FUZZY DSS

In the process of fuzzy DSS work with a fixed structure of the knowledge database and at a variable structure of the vector of input data $N_r < N$, the results of making decisions F undergo deformation. This is due to the fact that the values of the input parameters (signals) that do not take part in modeling of fuzzy DSS $\left(x_i = 0, i \in \{1, 2, ..., N\}\right)$, carry out negative impact on the result F through the appropriate fuzzy rules. To solve this problem the authors have developed an approach (based on two algorithms of editing of rules antecedents and consequents), which consists in correction of the rules of fuzzy knowledge databases at variation of input parameters that allows not to take into account the values of input signals $x_i = NI, i \in \{1, 2, ..., N\}$ (NI – not interested), which are not important for DM in the process of making decisions.

A block scheme of the editing algorithm of rules antecedents of fuzzy DSS is presented in Fig. 2.

Proposed by authors editing algorithms of rules antecedents of fuzzy DSS, whose project was developed in a computing environment MatLab, consists of the following stages (Fig. 2):

1. The input information of editing algorithm of rules antecedents is the name of subsystem of fuzzy DSS and the vector of values of the input linguistic variables [21].
2. With the help of onboard in MatLab the function readfis the structure of subsystem is read, whose name was introduced at the first stage [14].
3. With the help of the function getfis and its setting rules the rules of the knowledge database of this subsystem are read [1, 15].
4. Implementation of a cycle of passing by each meaning of the vector of the input variables: if this value corresponds to zero signals (indicates that the input variable is not interesting for DM and does not take part in the process of making decisions), then the value of the counter increases by one. Herewith one more cycle of passing by all rules FKD starts, during the implementation of which to the number of term, which corresponds to the number of zero meaning in the vector of input variables, assigns to the meaning of zero signal. Replacing of the term number in the rules database to a zero meaning means that this term will not influence on the process of aggregation due to corresponding fuzzy rules.
5. If no value of the vector of the input variables does not contain zero meaning or when the stage 5 is done completely for all zero meanings of the vector of the input variables then dynamically a new subsystem with such structure is created, the same as was entered at the stage 2, but with altered antecedents of FKD.

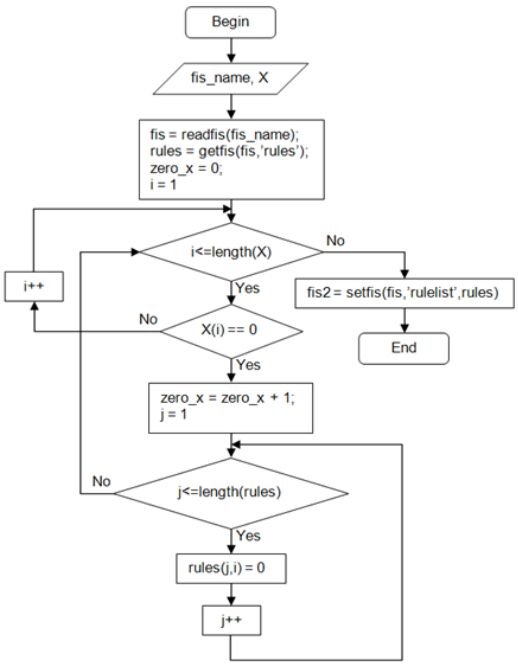

Fig. 2 – The block scheme of the editing algorithm of rules antecedents of fuzzy DSS

After editing of FKD antecedents of fuzzy DSS it is necessary also to edit FKD consequents according to modified antecedents.

The block scheme of the editing algorithm of rules consequents of fuzzy DSS is presented in Fig. 3.

Proposed by authors editing algorithms of rules consequents of fuzzy DSS consists of the following stages (Fig. 2):

1. To the input a name of a newly created system (fis2), the vector of input linguistic variables meanings (X) and matrix of the modified rules FKD (rules) are

given [14, 15].

2. A cycle of passing by matrix of the modified FKD rules is done: the values of antecedents for each FKD rule are added; the sum is divided on the amount of input variables that are not equal to zero value (devide = length(X) – zero_x; result = sum / devide); the result of division is analyzed and on its basis the consequent of relevant rule gets a value from 1 to 5 (1 – «L», 2 – «LM», 3 – «M», 4 – «MH», 5 – «H»).
3. After passing by all FKD rules and correction of consequents the value of the input signal of fuzzy DSS is calculated.

The particularity of the editing algorithm of consequents of FKD rules, the block scheme of which is presented in Fig. 3, is the fact that this algorithm should be performed only after the provisional implementation of the editing algorithm of rules antecedents of fuzzy DSS (Fig. 3), as the input data for realization of the algorithm according to Fig. 3 consist the results of realization of the algorithm according to Fig. 2.

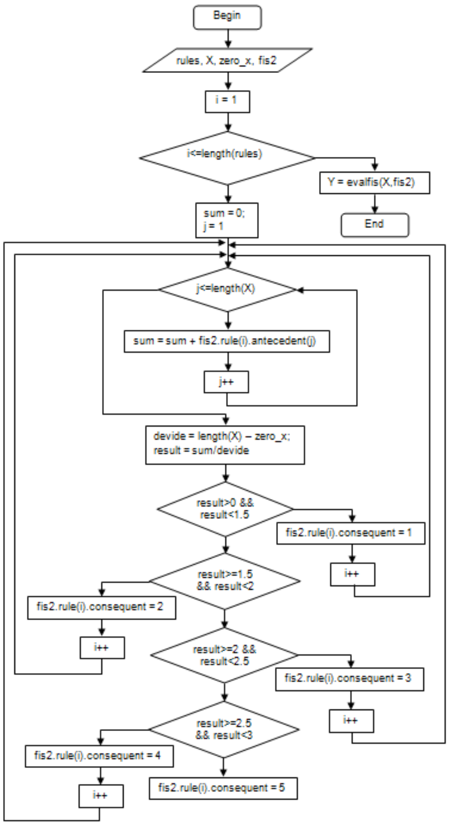

Fig. 3 – The block scheme of the editing algorithm of rules consequents of fuzzy DSS

These algorithms can be applied in the process of designing of fuzzy DSS with a variety structure of the input data, which are designed to assess the quality of cargo delivery.

5. SYNTHESIS OF FUZZY DSS

The project of fuzzy DSS is developed as a set of interacting subsystems. Their connection into a coherent system was made at the program level [21].

Interface of the project of fuzzy DSS (as in Fig. 1) when $x_1 = 2800$, $x_2 = 85$, $x_3 = 70$, $x_4 = 85$, $x_5 = 95$ was developed by means of GUI MatLab and is presented in Fig. 4.

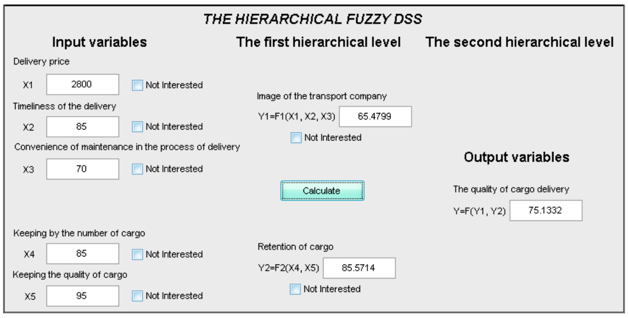

Fig. 4 – Interface of the project of fuzzy DSS

6. SIMULATION RESULTS

Simulation results of fuzzy DSS for different types of sets (I, II, III) of input data $\{x_1, x_2, x_3\}$ and at permanent values $x_4 = 80$ and $x_5 = 90$ are presented in the table 2.

Table 2. The results of fuzzy DSS work

	Value of factors								
	I			II			III		
x_1	4200	4200	4200	4200	4200	4200	4200	**4200**	4200
x_2	35,0	35,0	35,0	65,0	65,0	65,0	95,0	**95,0**	95,0
x_3	35,0	65,0	95,0	35,0	65,0	95,0	35,0	**65,0**	95,0
y_1	45,0	50,0	70,4	50,0	55,0	75,3	70,4	**75,3**	91,8
F	62,3	70,2	75,6	70,2	71,0	84,8	75,6	**84,8**	88,2

The results of fuzzy DSS work without and with application of the editing algorithm of the FKD rules when $x_1 = 3500$, $x_2 = 75$, $x_3 = 0$ or $x_3 = NI$, $x_4 = 85$, $x_5 = 75$ are presented in Fig. 5 and Fig. 6.

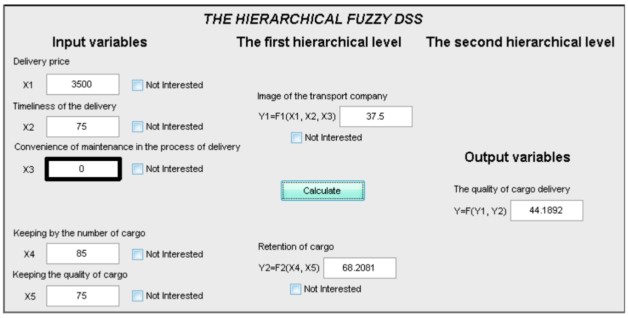

Fig. 5 – The results of fuzzy DSS work without application of the editing algorithm of the FKD rules

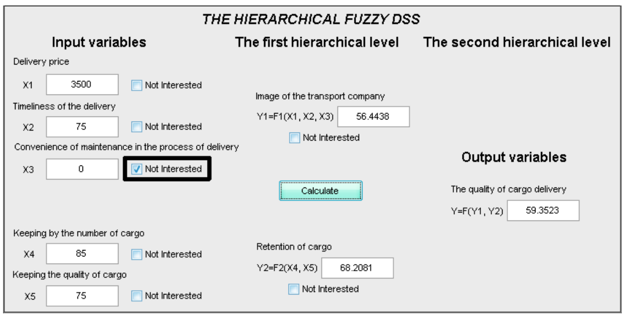

Fig. 6 – The results of fuzzy DSS work with application of the editing algorithm of the FKD rules

In the table 3 there are presented the results of the system work on three sets of the input data without application {I(–), II(–), III(–)} and with application {I(+), II(+), III(+)}, which was developed by the authors of the editing algorithm of the FKD rules for the evaluation of cargo delivery.

Table 3. The results of fuzzy DSS work

	Value of factors					
	I(-)	**I(+)**	**II(-)**	**II(+)**	**III(-)**	**III(+)**
x_1	50,0	50,0	50,0	50,0	**50,0**	**50,0**
x_2	35,0	35,0	65,0	65,0	**95,0**	**95,0**
x_3	0	NI	0	NI	**0**	**NI**
y_1	24,7	45,4	29,6	54,6	**50,0**	**75,3**
F	45,2	62,6	51,4	70,8	**70,2**	**84,8**

Simulation results (Tables 3, 4) show that the rate of quality F of cargo delivery system in the process of fuzzy DSS work at $x_1 = 50$, $x_2 = 95$, $x_3 = 65$ is 84.8 points. This figure without application of editing algorithm of the FKD rules at $x_1 = 50$, $x_2 = 95$, $x_3 = 0$ is 70.2 points. Zero value that was installed at the inlet x_3 means the interest of DM in this indicator in the process of decision making. But herewith the value $x_3 = 0$ influences on fuzzy DSS work that leads to results deformation of system simulation. The value of the output system signal (F) that was obtained using the editing algorithm of FKD rules at the same values of the input parameters of the system ($x_1 = 50$, $x_2 = 95$) and at the value of indicator (not included, NI – not interested), is equal to 84.8 points. The result of fuzzy DSS work (table 3) with application of the editing algorithm of the FKD ($F = 84{,}8$) coincides with the value of the output value of fuzzy DSS without application of the editing algorithm of the FKD with input parameters $x_1 = 50$, $x_2 = 95$, $x_3 = 65$ (table 2). Therefore, we can conclude that the indicator value x_3 almost does not influence on the result of the system work with application of the editing algorithm of the FKD rules that proves the effectiveness and feasibility of application of this algorithm in DSS with the variable structure of the vector of input data.

In table 4 there is presented a set of FKD rules of the first subsystem $y_1 = f_1(x_1, x_2, x_3)$ that undergo correction at the application of the editing algorithm of the FKD rules. Herewith $x_3 = L(0)$ corresponds to zero value of the input signal x_3, and $x_3 = NI$ to disinterest of DM in the input parameter x_3 in the process of decision making.

Table 4. Corrected rules database of the first subsystem $y_1 = f_1(x_1, x_2, x_3 = NI)$

№ of the rule	x_1	x_2	x_3	y_1	x_3	y_1
2	L	L	L(0)	L	NI	L
3	L	L	L(0)	L	NI	L
5	L	M	L(0)	LM	NI	LM
6	L	M	L(0)	LM	NI	LM
9	L	H	L(0)	M	NI	M
10	M	L	L(0)	L	NI	LM
12	M	L	L(0)	L	NI	LM
13	M	M	L(0)	LM	NI	M
15	M	M	L(0)	LM	NI	M
16	M	H	L(0)	M	NI	MH
18	M	H	L(0)	M	NI	MH
19	H	L	L(0)	LM	NI	M
20	H	L	L(0)	LM	NI	M
22	H	M	L(0)	M	NI	MH
24	H	M	L(0)	M	NI	MH
25	H	H	L(0)	M	NI	H
26	H	H	L(0)	M	NI	H

6. CONCLUSIONS

Application of the developed editing algorithm of the FKD rules of the intellectual DSS on fuzzy logic allows raising the effectiveness of management decision-making.

Simulation results of the developed DSS (table 2, 3, 4) confirm the effectiveness of application of the editing algorithm of the knowledge database in the process of designing and synthesis of the system for evaluating the quality of cargo delivery at variable structure of the vector of input data.

The approach considered by the authors on the example of knowledge base of fuzzy DSS correction with 5 input coordinates can be effectively applied to bigger dimension of the vector of the input coordinates, in particular, to correction of fuzzy DSS rules [18, 19] with 19 input coordinates.

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