Fuzzy Decision Making System for Model-Oriented Academia/Industry Cooperation: University Preferences

Galyna Kondratenko, Yuriy Kondratenko and Ievgen Sidenko

Abstract This paper discusses the effective models of cooperation of universities and IT companies, as well as the hierarchic approach towards projecting certain decision making support systems (DSS) based on fuzzy logic. Special attention is paid to fuzzy DSS as an advisor in choosing the most appropriate cooperation model for a certain department of universities eager to become partners within the frames of future cooperation with a certain IT company. The article features hierarchic structure, results of rule bases and DSS software based on the approximation of fuzzy systems with discrete output. It also contains the results of imitational DSS modeling based on the elaborated DSS developing the most rational model of cooperation for a university party of the cooperation of the "University—IT company" type.

Keywords Decision support system · Fuzzy logic · Membership function Linguistic term · Rule base · University-industry cooperation

1 Introduction

Scientific potential of higher educational institutions is a fundamental basis for the introduction of personal scientific achievements and developments (modern theories, inventions, up-to-date scientific projects etc.) into the spheres of industry, IT, and national economy altogether. The ability to create world-level competitive technologies concerning IT-engineering can be substantially geared up by

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increasing the level of interaction between the departments of universities and industrial producing companies. For instance, the formation of universities and IT companies dealing with IT development and introduction into academic industrial consortiums (AICs) opens up vast opportunities of Science-to-Business (S2B) and Business-to-Science (B2S) directions involving new technologies of programming and hardware, as well as increasing intellectual potential of both modern IT-companies and universities [1–3].

2 Related Works and Problem Statement

The problem of choosing the most efficient university-industry cooperation (UIC) model with an IT-company is something a certain university faces as a potential partner at the initial phase of cooperation. The analysis of asserted literature allows us to define a wide circle of basic factors influencing the UIC model within the frames of an AIC, for instance, the following could be listed: IT-students level of knowledge, their extent of participation in international exchange programs, their cooperation with existing IT-companies, the students' grades, levels of IT company staff's experience, educational potential of the said IT company, IT-certification of its lecturers, business workshops held at universities, startup experience, the amount of grants distributed to finance the scientific research processes, level of articles published etc. [3–5]. Based on the listed factors both the university and the company must search for the best partnership considering the most rational cooperative model from the corporate interest point of view. This task is hard due to the fact that certain factors can only be represented with vague and fuzzy evaluations, and the search process is connected with fuzzy information based on multidimensional fuzzy dependencies [6–10].

Intellectual DSS developed based on up-to-date methods, technologies and approaches towards system analysis, prognostication, fuzzy logic, neural networks, AI can contribute to the efficiency increase in cooperation. Involvement of these methods into the development of modern DSS allows to process vast amounts of various data on a brand new level of interaction between a human operator (HO) and a computer system [4, 5, 7, 10–12].

In order to choose a rational cooperation model within the frames of an AIC hierarchically-organized DSS based on fuzzy logic discrete output is considered to be appropriate. Previous surveys, research and analysis of the existing successful experience of AIC cooperation prove that modern solution to the choice of cooperative model problem features 4 alternative models E_i, $(i = 1 \ldots m)$ to choose from where $(m = 4)$ is the optimal one. In this case the E_1 corresponds to the A1 model (interaction between a university and an IT-company aimed at education and knowledge enrichment, experiential exchange and staff preparation for an IT company); E_2 corresponds to A2 model (structuration and maintenance of certification of cooperation results); E_3 corresponds to B model (creation of joint scientific research center and the development of joint scientific projects); E_4

corresponds to C model (creation of student scientific research clusters and creation of independent enterprises aimed at business and startup implementation). The efficient selection of the cooperation model depends on the chosen $x_j, (j = 1, 2, \ldots, n)$ factors characterizing each of the partners of the future AIC between a university and an IT company [3, 6, 7].

The implementation of the bespoken models of cooperation requires considering and processing vast amounts of input data based on the analysis of previous experience of cooperation between the parties of interest, advantages and directions of development, scientific and educational levels of the future AIC participants, level of students' and lecturers' involvement etc. A poorly chosen cooperation model, as well as the inconsideration of certain cooperation requirements within the frames of the AIC can lead to unexpected and unaccounted consequence, for instance, a considerable loss of intellectual and\or material resources, decrease of educational and qualification levels of the lecturers and specialists, lesser potential and ability of creative approach [3–9].

The aim of current research is development and approbation of an intellectual DSS based on fuzzy logic allowing the university to choose the most rational cooperation model to establish an AIC, considering all the preferences of the university as potential partner, basic values of its activity and scientific potential of the IT department of the university.

3 Analysis of Existing Methods and Approaches for Choosing the Model of Cooperation Between the University and the IT-Company

The choice of a proper cooperation model between a university and an IT company is quite a complicated process for many reasons, for instance, multiple factors of evaluation, complexity of preliminary consideration of all possible stages of decision making, absence of any possibility to define the values of certain input factors, insufficient knowledge of up-to-date IT technologies' peculiarities or insufficient material base etc. [3, 7].

In order to choose the most efficient (appropriate) cooperation model one might use the following [13–19]: (a) Delphi method; (b) pairwise comparisons method; (c) Saati method of analytic hierarchy process etc.

The Delphi method is based on a thoroughly developed procedure of consequential individual questioning of the experts by making them fill in the survey questionnaire. It is accompanied by constant updating of the experts on the results of the processing before the answers are obtained. The expertise lasts a few rounds until most of the experts acquire the appropriate result according to their collective judgment. The median of final answers of all the experts is considered to be the ultimate evaluation [16, 21]. This method is undergoing constant improvement due to the ability of combining it with other methods. New modifications of the Delphi method provide increased comprehensive methodology, rapid and exact acquiring of joint expert evaluations.

The pairwise comparisons method means direct involvement of the expert evaluating the aims. According to this method the aims are being compared in all possible combinations. Each pair has a best goal chosen from. The processing of evaluation matrix allows determining the values of aims, thus distinguishing their relative importance levels [19, 20].

Saati method of analytic hierarchy process (AHP) is a calculations tool of system approach towards the complicated problems of decision making. It allows the decision maker to find the option of solving the problem, to find such an alternative which is the most appropriate according to his understanding of the essence of the problem and given requirements towards its solution [14–17, 19]. Building a hierarchical structure of the task allows to analyze all the possible necessary and sufficient elements of hierarchy. The models available for selection within the frames of the AIC are A1, A2, B, C [3, 6, 7] as well as their combinations A1&A2, A2&B, B&C etc.

The methods mentioned above have certain disadvantages: necessity of experts' evaluations accordance calculation; limited levels of hierarchy and pairwise comparison matrix size; necessity to maintain constant contact with the experts for questioning, necessity to update the DSS structure along with the change of input vector coordinates etc. [18].

The fuzzy logic inference method allows to perform a multifactorial evaluation of possible cooperation level and a choice of the appropriate model (A1, A2, B, C) for the university cooperation with the IT company without limits to the number of input coordinates and production rules. It is very convenient to use because of easily adjustable parameters and availability of decision making under the circumstances of uncertainty. The development of fuzzy logic selection of DSS algorithms for cooperation under uncertainty circumstances is one of the most prospective direction in modern IT sphere, considering the formation of input expert data with a high level of indetermination and variable structure of input coordinates vector [6, 7, 20–24].

4 The Structure of Fuzzy DSS for Choosing the Expedient UIC Model for University Department

According to the experience gained by the experts in projecting specific fuzzy systems for different purposes, the one-level structure of DSS under conditions of high-dimensional $X = \{x_j\}, j = 1 \ldots n$ input coordinates (factors, values) decreases the sensitivity of fuzzy rules towards the alternation of input coordinates $x_j, (j = 1, 2, \ldots, n)$. First of all this is linked to the complexity of establishing appropriate fuzzy rules for the implementation of all the possible relations between the input and output parameters of the system $y_k = f(x_1, x_2, \ldots, x_n),\ k = 1 \ldots K$ [7].

Let us observe in detail the procedure of appropriate cooperation model definition the authors propose for the university and its IT department considering its preferences towards the future partner within the frames of the AIC. The authors have developed a separate module of DSS to choose the necessary UIC model between the department and the IT company including 17 input $X = \{x_j\}, j = 1\ldots17$ coordinates and one output y, that are interconnected by fuzzy dependencies

$$y_k = f(x_1, x_2, \ldots, x_{17}), k = \overline{1, 7}$$

of the corresponding rule bases of 7 fuzzy subsystems FSS1, FSS2,…, FSS7 (Fig. 1). The input variables $X = (x_1, x_2, \ldots, x_{17})$ are x_1—level of scientific value of masters' and bachelors' thesis papers (MTP and BTP respectfully); x_2—practical implementation of BTP and MTP; x_3—accordance of BTP and MTP to the direction of research; x_4—level of IT-experience among the students of the department; x_5—participation of the students in the international exchange programs; x_6—level of interaction between students and IT companies; x_7—students' grades; x_8—level of the departments research work; x_9—number of patents; x_{10}—number of grants; x_{11}—level of published scientific research at university; x_{12}—amount of scientific publications; x_{13}—category and rating of the university; x_{14}—level of IT-certification among the lecturers; x_{15}—level of held business-courses and workshops; x_{16}—experience in organization of student companies; x_{17}—experience in managing a joint collective of people to implement IT-related projects [6, 7].

The principle of DSS approximation for choosing the appropriate UIC model lies within using the fuzzy logical equations based on the knowledge matrix (Table 1) or a system of fuzzy logic statements (1) [12, 20].

Fuzzy logical statements (1) obtained from the knowledge matrix (Table 1) [20].

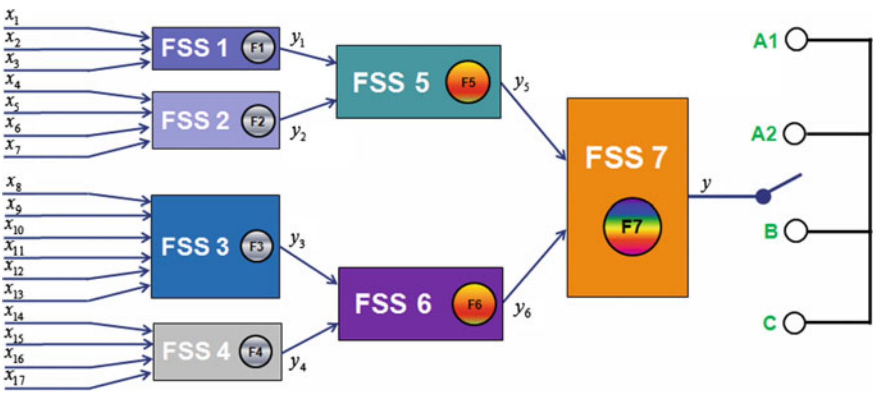

Fig. 1 Fuzzy DSS structure for choosing the appropriate UIC model for the university department within the framework of cooperation with the IT company

Table 1 Knowledge matrix $y = f(x_1, x_2, \ldots, x_n)$

Number of combination	x_1	x_2	...	x_i	...	x_n	y
11	a_1^{11}	a_2^{11}	…	a_i^{11}	…	a_n^{11}	d_1
12	a_1^{12}	a_2^{12}	…	a_i^{12}	…	a_n^{12}	
	…		…	…	…	…	
$1k_1$	$a_1^{1k_1}$	$a_2^{1k_1}$	…	$a_i^{1k_1}$	…	$a_n^{1k_1}$	
	…			…		…	
$j1$	a_1^{j1}	a_2^{j1}		a_i^{j1}		a_n^{j1}	d_j
$j2$	a_1^{j2}	a_2^{j2}		a_i^{j2}		a_n^{j2}	
	…			…		…	
jk_j	$a_1^{jk_j}$	$a_2^{jk_j}$		$a_i^{jk_j}$		$a_n^{jk_j}$	
	…			…		…	
$m1$	a_1^{m1}	a_2^{m1}		a_i^{m1}		a_n^{m1}	d_m
$m2$	a_1^{m2}	a_2^{m2}		a_i^{m2}		a_n^{m2}	
	…			…		…	
mk_m	$a_1^{mk_m}$	$a_2^{mk_m}$		$a_i^{mk_m}$		$a_n^{mk_m}$	

$$
\begin{aligned}
&\text{IF } \left(x_1 = a_1^{11} \text{ AND } x_2 = a_2^{11} \text{ AND } \ldots \text{ AND } x_n = a_n^{11}\right) \text{ OR}\\
&\left(x_1 = a_1^{12} \text{ AND } x_2 = a_2^{12} \text{ AND } \ldots \text{ AND } x_n = a_n^{12}\right) \text{ OR } \ldots\\
&\text{OR } \left(x_1 = a_1^{1k_1} \text{ AND } x_2 = a_2^{1k_1} \text{ AND } \ldots \text{ AND } x_n = a_n^{1k_1}\right) \text{ THEN } y = d_1 \text{ ELSE}\\
&\text{IF } \left(x_1 = a_1^{21} \text{ AND } x_2 = a_2^{21} \text{ AND } \ldots \text{ AND } x_n = a_n^{21}\right) \text{ OR}\\
&\left(x_1 = a_1^{22} \text{ AND } x_2 = a_2^{22} \text{ AND } \ldots \text{ AND } x_n = a_n^{22}\right) \text{ OR } \ldots\\
&\text{OR } \left(x_1 = a_1^{2k_2} \text{ AND } x_2 = a_2^{2k_2} \text{ AND } \ldots \text{ AND } x_n = a_n^{2k_2}\right) \text{ THEN } y = d_2 \text{ ELSE}\\
&\ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots\\
&\text{IF } \left(x_1 = a_1^{m1} \text{ AND } x_2 = a_2^{m1} \text{ AND } \ldots \text{ AND } x_n = a_n^{m1}\right) \text{ OR}\\
&\left(x_1 = a_1^{m2} \text{ AND } x_2 = a_2^{m2} \text{ AND } \ldots \text{ AND } x_n = a_n^{m2}\right) \text{ OR } \ldots\\
&\text{OR } \left(x_1 = a_1^{mk_m} \text{ AND } x_2 = a_2^{mk_m} \text{ AND } \ldots \text{ AND } x_n = a_n^{mk_m}\right) \text{ THEN } y = d_m
\end{aligned}
\qquad (1)
$$

where a_i^{jk} is a linguistic term (evaluation) i variable (x_i) to evaluate the j decision (d_j) according to the k rule [20, 25].

It allows to calculate the membership functions (MF) for various types of decisions d_j, $j = \overline{1, m}$ provided the input variables are fixed at x_i, $i = \overline{1, n}$ for a fuzzy system. The approximation task is defining the decision d^* that has the biggest value of MF:

$$\mu^{d^*}\left(x_1^*, x_2^*, \ldots, x_n^*\right) = \max_{j = \overline{1, m}}\left(\mu^{d_j}\left(x_1^*, x_2^*, \ldots, x_n^*\right)\right).$$

Let us observe the method for formation of knowledge matrix and processing fuzzy information while choosing the most rational cooperation model for the department of the university with IT-company based on the first subsystem FSS1 $y_1 = f_1(x_1, x_2, x_3)$ of the fuzzy DSS (Fig. 1).

Let us define the input and output coordinates of the system along with their characteristic parameters [7].

Input linguistic variables:

- X_1—level of scientific value of masters' and bachelors' thesis papers (MTP and BTP respectfully): range of vary—[0 100], number of linguistic terms (LT)—3 ("low", "medium", "high"), shape of MF—triangular [25–27];
- X_2—BTP and MTP's practical implementation value:): range of vary—[0 100], number of LTs—3 ("low", "medium", "high"), shape of MF—triangular;
- X_3—correspondence of BTPs and MTPs with the research direction of the department: range of vary—[0 100], number of LTs—3 ("low", "medium", "high"), shape of MF—triangular.

Output linguistic variable:

- y—BTP and MTP level evaluation: range of vary—[0 100], number of LTs—5 ("low"—L, "lower than medium"—LM, "medium"—M, "higher than medium"—HM, "high"—H), shape of MF—triangular.

Let us form the models for all the triangular LTs for the evaluation of input and output variables of the subsystem $y_1 = f_1(x_1, x_2, x_3)$, as well as the rule base and correspondent knowledge matrix. We choose the following parameters for the triangular LT models $.3em\tilde{A} = (a_1, a_0, a_2)$ for all the variables x_1, x_2, x_3, y_1:

- X_1—$low = (0, 0, 50)$; $medium = (0, 50, 100)$; $high = (50, 100, 100)$;
- X_2—$low = (0, 0, 50)$; $medium = (0, 50, 100)$; $high = (50, 100, 100)$;
- X_3—$low = (0, 0, 50)$; $medium = (0, 50, 100)$; $high = (50, 100, 100)$;
- X_4—$\begin{cases} L = (0, 0, 25);\ LM = (0, 25, 50);\ M = (25, 50, 75); \\ HM = (50, 75, 100);\ H = (75, 100, 100) \end{cases}$.

LT graphic representation for the variables x_1, x_2, x_3 and y_1 is at Fig. 2.

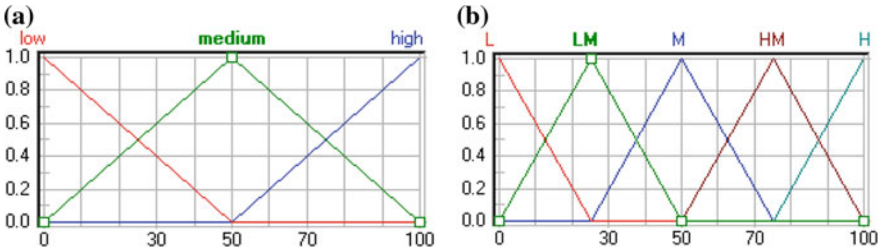

Fig. 2 LT with triangular shape of MF for variables x_1, x_2, x_3 (**a**) and y_1 (**b**)

Table 2 Rule base for subsystem $y_1 = f_1(x_1, x_2, x_3)$

Number of rule	x_1	x_2	x_3	y_1
1	Low	Low	Low	L
2	Low	Low	Medium	L
3	Low	Low	High	LM
4	Low	Medium	Low	L
5	Low	Medium	Medium	LM
6	Low	Medium	High	M
7	Low	High	Low	LM
8	Low	High	Medium	LM
9	Low	High	High	M
10	Medium	Low	Low	L
11	Medium	Low	Medium	LM
12	Medium	Low	High	M
13	Medium	Medium	Low	LM
14	Medium	Medium	Medium	M
15	Medium	Medium	High	HM
16	Medium	High	Low	M
17	Medium	High	Medium	HM
18	Medium	High	High	HM
19	High	Low	Low	LM
20	High	Low	Medium	M
21	High	Low	High	M
22	High	Medium	Low	M
23	High	Medium	Medium	HM
24	High	Medium	High	HM
25	High	High	Low	HM
26	High	High	Medium	H
27	High	High	High	H

Let us form a rule base (Table 2) and a knowledge matrix (Table 3) based on formerly gained expert data and knowledge, using the previously developed LT models with triangular shape of MF for x_1, x_2, x_3, y_1 variables [7, 20].

Knowledge matrix (Table 3) [20, 28, 29] is formed according to the rule base (Table 2) by combining the rules according to the output value $y_1 \in \{L, LM, M, HM, H\}$.

When the user enters data $X^* = (x_1^*, x_2^*, x_3^*)$, the best possible decision for the subsystem $y_1 = f_1(x_1, x_2, x_3)$ is defined. On the next hierarchy level (Fig. 1) it is represented by the input coordinate $y_1 \in \{L, LM, M, HM, H\}$ of the corresponding subsystem FSS5 $y_5 = f_5(y_1, y_2)$.

Therefore, fuzzy logical statements (1) can be represented as the fuzzy logical equations (2) by triangular MF (Fig. 2) and a knowledge matrix (Table 3):

Table 3 Knowledge matrix for subsystem $y_1 = f_1(x_1, x_2, x_3)$

Number of rule and combination		x_1	x_2	x_3	y_1
1	11	Low	Low	Low	**L**
2	12	Low	Low	Medium	
4	13	Low	Medium	Low	
10	14	Medium	Low	Low	
3	21	Low	Low	High	**LM**
5	22	Low	Medium	Medium	
7	23	Low	High	Low	
8	24	Low	High	Medium	
11	25	Medium	Low	Medium	
13	26	Medium	Medium	Low	
19	27	High	Low	Low	
6	31	Low	Medium	High	**M**
9	32	Low	High	High	
12	33	Medium	Low	High	
14	34	Medium	Medium	Medium	
16	35	Medium	High	Low	
20	36	High	Low	Medium	
21	37	High	Low	High	
22	38	High	Medium	Low	
15	41	Medium	Medium	High	**HM**
17	42	Medium	High	Medium	
18	43	Medium	High	High	
23	44	High	Medium	Medium	
24	45	High	Medium	High	
25	46	High	High	Low	
26	51	High	High	Medium	**H**
27	52	High	High	High	

$$
\begin{aligned}
&\mu^{L}(x_1, x_2, x_3) = \left(\mu^{low}(x_1) \wedge \mu^{low}(x_2) \wedge \mu^{low}(x_3)\right) \vee \\
&\left(\mu^{low}(x_1) \wedge \mu^{low}(x_2) \wedge \mu^{medium}(x_3)\right) \vee \left(\mu^{low}(x_1) \wedge \mu^{medium}(x_2) \wedge \mu^{low}(x_3)\right) \vee \\
&\left(\mu^{medium}(x_1) \wedge \mu^{low}(x_2) \wedge \mu^{low}(x_3)\right), \\
&\mu^{LM}(x_1, x_2, x_3) = \left(\mu^{low}(x_1) \wedge \mu^{low}(x_2) \wedge \mu^{high}(x_3)\right) \vee \\
&\left(\mu^{low}(x_1) \wedge \mu^{medium}(x_2) \wedge \mu^{medium}(x_3)\right) \vee \left(\mu^{low}(x_1) \wedge \mu^{high}(x_2) \wedge \mu^{low}(x_3)\right) \vee \\
&\left(\mu^{low}(x_1) \wedge \mu^{high}(x_2) \wedge \mu^{medium}(x_3)\right) \vee \ldots \vee \left(\mu^{high}(x_1) \wedge \mu^{low}(x_2) \wedge \mu^{low}(x_3)\right), \\
&\ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \\
&\mu^{H}(x_1, x_2, x_3) = \left(\mu^{high}(x_1) \wedge \mu^{high}(x_2) \wedge \mu^{medium}(x_3)\right) \vee \\
&\left(\mu^{high}(x_1) \wedge \mu^{high}(x_2) \wedge \mu^{high}(x_3)\right).
\end{aligned} \tag{2}
$$

Let us assume the user entry data $x_1^* = 60$; $x_2^* = 30; x_3^* = 90$, concerning the first subsystem $y_1 = f_1(x_1, x_2, x_3)$ for BTP and MTP level evaluations. Based on the direct (vertical) LT model with triangular shape of MF (3) we fuzzificate the input coordinates FSS1, defining the membership degrees of vector components for X^* towards the corresponding LTs (Fig. 2) [25–29]:

$$\mu_{.3em\sim A}(x) = \begin{cases} 0, \quad \text{for } (x < a_1) \cup (x > a_2) \\ \dfrac{x - a_1}{a_0 - a_1}, \quad \text{for } a_1 \leq x \leq a_0, \text{ if } a_1 \neq a_0 \\ \dfrac{a_2 - x}{a_2 - a_0}, \quad \text{for } a_0 < x \leq a_2, \text{ if } a_0 \neq a_2 \\ 1, \text{ other cases} \end{cases} \tag{3}$$

The result of the fuzzification is the following:

$$\begin{aligned} &x_1^*: \mu_{low}(60) = 0;\ \mu_{medium}(60) = 0,8;\ \mu_{high}(60) = 0,2; \\ &x_2^*: \mu_{low}(30) = 0,4;\ \mu_{medium}(30) = 0,6;\ \mu_{high}(30) = 0; \\ &x_3^*: \mu_{low}(90) = 0;\ \mu_{medium}(90) = 0,2;\ \mu_{high}(90) = 0,8. \end{aligned}$$

Then the calculated membership degrees substitute to the system of Eq. (2) and we obtain the LT vector of membership degrees for the LT output signal $\mu^{d_j}(60, 30, 90) \in \{0;\ 0,\ 2;\ 0,\ 4;\ 0,\ 6;\ 0\}$, $d_j \in \{L, LM, M, HM, H\}$, $j = \overline{1,5}$ (4), where

$$\begin{aligned} &\mu^L(60,\ 30,\ 90) = (0 \wedge 0,\ 4 \wedge 0) \vee \ldots \vee (0,8 \wedge 0,\ 4 \wedge 0) = 0; \\ &\mu^{LM}(60,\ 30,\ 90) = (0 \wedge 0,\ 4 \wedge 0,\ 8) \vee \ldots \vee (0,\ 2 \wedge 0,\ 4 \wedge 0) = 0,2; \\ &\mu^M(60,\ 30,\ 90) = (0 \wedge 0,\ 6 \wedge 0,\ 8) \vee \ldots \vee (0,2 \wedge 0,\ 6 \wedge 0) = 0,4; \end{aligned} \tag{4}$$

$$\begin{aligned} &\mu^{HM}(60,\ 30,\ 90) = (0,8 \wedge 0,\ 6 \wedge 0,\ 8) \vee (0,8 \wedge 0 \wedge 0,\ 2) \vee \ldots \\ &(0,\ 8 \wedge 0 \wedge 0,\ 8) \vee (0,2 \wedge 0,\ 6 \wedge 0,\ 2) \vee (0,\ 2 \wedge 0,\ 6 \wedge 0,\ 8) \vee \ldots \\ &(0,\ 2 \wedge 0 \wedge 0) = (0,\ 6 \vee 0 \vee 0 \vee 0,\ 2 \vee 0,\ 2 \vee 0) = 0,\ 6; \\ &\mu^H(60,\ 30,\ 90) = (0,\ 2 \wedge 0 \wedge 0,\ 2) \vee (0,\ 2 \wedge 0 \wedge 0,\ 8) = 0. \end{aligned}$$

Below is the matrix implementation of the approximation procedure for $y_1 = f_1(x_1, x_2, x_3)$ with discrete output (Table 3), as a result of transformations performed upon a system of fuzzy logic equations (2), (4) using the t-norm $(\wedge)$ *MIN* and s-norm $(\vee)$ *MAX* operators. A combined set of rules with appropriate membership degrees in the universal and numerical forms are in the matrix implementation [20, 25].

№	x_1	x_2	x_3			
1	$\mu^{low}(x_1)$	$\mu^{low}(x_2)$	$\mu^{low}(x_3)$	}min		
… … …					} max	
10	$\mu^{medium}(x_1)$	$\mu^{low}(x_2)$	$\mu^{low}(x_3)$	}min	(0)	
3	$\mu^{low}(x_1)$	$\mu^{low}(x_2)$	$\mu^{high}(x_3)$	}min		
… … …					} max	
19	$\mu^{high}(x_1)$	$\mu^{low}(x_2)$	$\mu^{low}(x_3)$	}min	(0,2)	} max
6	$\mu^{low}(x_1)$	$\mu^{medium}(x_2)$	$\mu^{high}(x_3)$	}min		
… … …					} max	
22	$\mu^{high}(x_1)$	$\mu^{medium}(x_2)$	$\mu^{low}(x_3)$	}min	(0,4)	
15	**0,8**	**0,6**	**0,8**	}min (0,6)		
17	**0,8**	**0**	**0,2**	}min (0)	} max	
18	**0,8**	**0**	**0,8**	}min (0)		(0,6)
23	**0,2**	**0,6**	**0,2**	}min (0,2)	(0,6)	
24	**0,2**	**0,6**	**0,8**	}min (0,2)		
25	**0,2**	**0**	**0**	}min (0)		
26	$\mu^{high}(x_1)$	$\mu^{high}(x_2)$	$\mu^{medium}(x_3)$	}min	} max	
27	$\mu^{high}(x_1)$	$\mu^{high}(x_2)$	$\mu^{high}(x_3)$	}min	(0)	

We define the best decision d^* if $X^* = (x_1^*, x_2^*, x_3^*)$, where, for instance, $x_1^* = 60$; $x_2^* = 30$; $x_3^* = 90$, for the first subsystem FSS1 $y_1 = f_1(x_1, x_2, x_3)$. The best is the decision, whereupon

$$\mu^{d^*}(X^*) = \max_{j=\overline{1,5}} \left(\mu^{d_j}(60, 30, 90) \in \{0;\ 0,2;\ 0,4;\ 0,6;\ 0\}\right) = 0.6$$

Since $\mu^{d^*}(X^*) = 0.6$ is in accordance with decision d_4^*, the BTP and MTP evaluation level y_1 corresponds to the LT $\{HM\}$—"higher than medium".

According to the method mentioned above we define the best decision (UIC model for the university department) for the resulting subsystem $y = f_7(y_5, y_6)$, where y_5—general educational level of the students, y_6—level of research\business orientation of university lecturers, y—UIC model for the university department. Knowledge matrix (partial set of rules) for the corresponding subsystem is at Table 4.

Table 4 Partial set of rules of the knowledge matrix for subsystem $y = f_7(y_5, y_6)$

№ of rule and combination	1	2	6	16	3	4	5	… … …	17	21	22
	11	**1**2	**1**3	**1**4	**2**1	**2**2	**2**3		**2**8	**2**9	**2**10
y_5	L	L	LM	HM	L	L	L		HM	H	H
y_6	L	LM	L	L	M	HM	H		LM	L	LM
y	**A1**	**A1**	**A1**	**A1**	**A2**	**A2**	**A2**		**A2**	**A2**	**A2**
№ of rule and combination	9	10	13	14	15	18	19	20	23	24	25
	31	**3**2	**3**3	**3**4	**3**5	**3**6	**4**1	**4**2	**4**3	**4**4	45
y_5	LM	LM	M	M	M	HM	HM	HM	H	H	H
y_6	HM	H	M	HM	H	M	HM	H	M	HM	H
y	**B**	**B**	**B**	**B**	**B**	**B**	**C**	**C**	**C**	**C**	**C**

Thus, based on the authors proposed fuzzy DSS (Fig. 1) exists a choosing of appropriate UIC model within the cooperation with IT company using discrete logical inference. The advantage of this approach is that the DSS result is a specific decision $y \in \{A1, A2, B, C\}$ (Table 4). In addition, when the values of membership degrees $\mu^{d^*}(X^*)$ are similar, a decision making human can choose several variants of decisions (combined models), for example $A1\&A2$, $A2\&B$, $B\&C$ etc. It allows more accurately choose the appropriate UIC model and reduce the time of result calculation by eliminating the need for defazzification as in the case in systems with continuous logical inference [30–33].

Therefore, the UIC model for the IT department of Petro Mohyla Black Sea National University within the framework of cooperation with IT company is the combined model A1&A2 by models A1 and A2 (Table 4), because $\mu^{d^*}(X^*) = \max_{j=\overline{1,4}}\left(\mu^{d_j}(60, 30, 90, \ldots, 10) \in \{0, 5; 0, 5; 0, 2; 0\}\right) = 0.5$ that corresponds to the LTs (decisions) $\{A1, A2\}$. Intermediate results of discrete logical inference are shown below:

$$y_1 = f_1(x_1, x_2, x_3) \Rightarrow y_1 \in \{HM\},\ \mu^{HM} = 0.6,\ X^* = (60, 30, 90)$$
$$y_2 = f_2(x_4, x_5, x_6, x_7) \Rightarrow y_2 \in \{HM\},\ \mu^{HM} = 0.7,\ X^* = (70, 60, 80, 75)$$
$$y_3 = f_3(x_8, x_9, \ldots, x_{13}) \Rightarrow y_3 \in \{LM\},\ \mu^{LM} = 0.6,\ X^* = (45, 30, 25, 40, 15, 4)$$
$$y_4 = f_4(x_{14}, \ldots, x_{17}) \Rightarrow y_4 \in \{L, LM\},\ \mu^{L} = 0.5,\ \mu^{LM} = 0.5,\ X^* = (10, 20, 15, 10)$$
$$y_5 = f_5(y_1, y_2) \Rightarrow y_5 \in \{HM\},\ \mu^{HM} = 0.6,\ Y^* = (HM, HM)$$
$$y_6 = f_6(y_3, y_4) \Rightarrow y_6 \in \{L, LM\},\ \mu^{L} = 0.5,\ \mu^{LM} = 0.5,\ Y^* = (LM, \{L, LM\})$$
$$y = f_7(y_5, y_6) \Rightarrow y \in \{A1, A2\},\ \mu^{A1} = 0.5,\ \mu^{A2} = 0.5,\ Y^* = (HM, \{L, LM\})$$

So, having on the inputs of the resulting subsystem $y = f_7(y_5, y_6)$ corresponding decisions $Y^* = (HM, \{L, LM\})$, a nonzero value of membership degrees will have two rules $Rule16$: $\{HM, L\}$ and $Rule17$: $\{HM, LM\}$. The result is two models A1 and A2.

In contrast to the continuous logical inference developed DSS with discrete logical inference (output signal) allows choosing several models (as at Petro Mohyla Black Sea National University).

5 Conclusions

The necessity of development of intellectual DSS in the AIC sphere can also be explained by the increase in complexity of processing scattered, incomprehensive or controversial data. At the project and implementation stage for the DSS there is a number of certain methodological and technical problems the developers stumble upon directly. For instance, in Ukraine we can name the following problems: absence of conceptual integrity and correspondence between certain traits and methods of engineering knowledge; lack of certified experts in the given area; low adaptive ability of the existing software; absence of the technical and economical values for the efficiency of such systems; the empiric nature of the tool selection procedure and testing, as well as the absence of unified criteria [2, 4–7, 11].

It is of paramount importance for now to develop the scheme of selection of partnership models based on the developments in the field of multifactorial evaluation of future cooperation levels between universities and IT-companies. Implementation of the fuzzy logic-based DSS gives an opportunity to choose the best model for the "University—IT company" consortium development from the point of view of the existing successfully operating consortiums and successful results of cooperation between universities and IT companies [7].

The performed analysis of the existing methods and approaches towards the choice of the appropriate UIC model for the IT department of the university with an IT company shows that upon increasing the input DSS parameters and the necessity of input coordinates vector there emerges a necessity to apply the intellectual methods and approaches based on fuzzy logic principles [20, 21].

The authors have represented the theoretically-methodological approach towards the hierarchic organization of DSS for choosing UIC model between universities and IT companies within the frames of the AIC with the implementation of the processing procedures of unclear expert data by using the triangular shape LTs [7, 20, 25].

Structure and rule base for a multilevel fuzzy logic-based DSS have been developed. They give an opportunity to present the decision making processes in the hierarchically organized DSS and graphically visualize them to a larger extent [16].

Besides, the analysis performed by the authors of this article on the materials of an existing successful innovational cooperation of academic educational institutions and IT companies [7–10] confirms that the creation of various "University-IT company" type entities and consortiums on purpose of finding solutions to the current and potential problems based on mutual work in the IT and Internet-communications' sphere is an extremely prospective direction for those who want to increase the efficiency of higher education field as well. In particular, the National Aerocosmic University "Kharkiv Aviation Institute" named after M. E. Zhukovskiy, Odessa National Polytechnic University, Yuriy Fedkovych Chernivtsi National University, Chernihiv State University, Petro Mohyla Black Sea National University, Institute of Cybernetics of National Academy of Sciences of Ukraine and others are members of such international academic-industrial consortia, which includes universities and IT-companies from Great Britain, Spain, Italy, Portugal, Ukraine and Sweden [3–6]. This consortium is created to develop and implement models of cooperation between universities and industry (IT companies) such as A1, A2, B and C within the project TEMPUS-CABRIOLET 544497-TEMPUS-1-2013-1-UK-TEMPUS-JPHES "Model-oriented approach and Intelligent Knowledge–Based System for Evolvable Academia-Industry Cooperation in Electronics and Computer Engineering" (2013–2017).

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