

# Computerized System for Cooperation Model's Selection based on Intelligent Fuzzy Technique

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**Abstract.** In this paper, the current state of the academic and industrial cooperation, as well as intelligent fuzzy technique for solving the task of cooperation model's selection in academia-industry collaboration are analyzed. The choice of cooperation model is an actual and important topic for the constant and substantial progress in increasing the quality of education for higher education systems of the different countries. Successful academia-industry cooperation will promote more active implementation of compatible programs and projects. One of the perspective approach to solve the current problem of cooperation model's selection is based on the implementation of the computerized systems or decision support systems (DSSs). In addition, existing software tools for the development of the DSSs based on intelligent fuzzy technique are analyzed. Among their limitations are: the restrictive numbers of aggregation and defuzzification methods; a limited number of membership functions types; the lack of discrete fuzzy logic output. The authors developed a computerized system (DSS) for cooperation model's selection based on intelligent fuzzy technique, in particular, based on Mamdani-type fuzzy inference engine which allows: (a) more flexible settings for input signals, (b) the use of more wide row of existing methods for aggregation and defuzzification in fuzzy data processing, and (c) outputting results in both discrete and continuous forms. DSS's testing results for several real examples of academia-industry cooperation confirm the correctness and efficiency of cooperation model's selection. Developed based on C# software for intelligent DSS expands the functionality to research, analyze and solve the corresponding task of cooperation model's selection.

**Keywords:** academia-industry cooperation, cooperation model's selection, DSS, fuzzy inference engine, discrete output, continuous output, membership function, aggregation, defuzzification.

## 1 Introduction

Selection of cooperation model is and actual and important topic for continuous and considerable development of education quality in higher education institutions of the country, its theoretical and, especially, practical part [1-3]. Also one cannot disregard the fact that institutions are in the foreground of research, which results are applied

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directly to the tasks confronted by the industry. The intercommunication between the industry and the scientific community is rather complicated, it has countless number versatile aspects – from cooperation during schooling of a new generation of beginner-level specialists to partnership in research aimed towards solving problems of tomorrow [4-7]. Successful cooperation is going to assist a more active implementation of joint programs and projects. Besides, within partnership students, teachers and scientific workers of higher education institutions are going to have opportunities to raise their competitiveness in the job market [2, 4, 8-10].

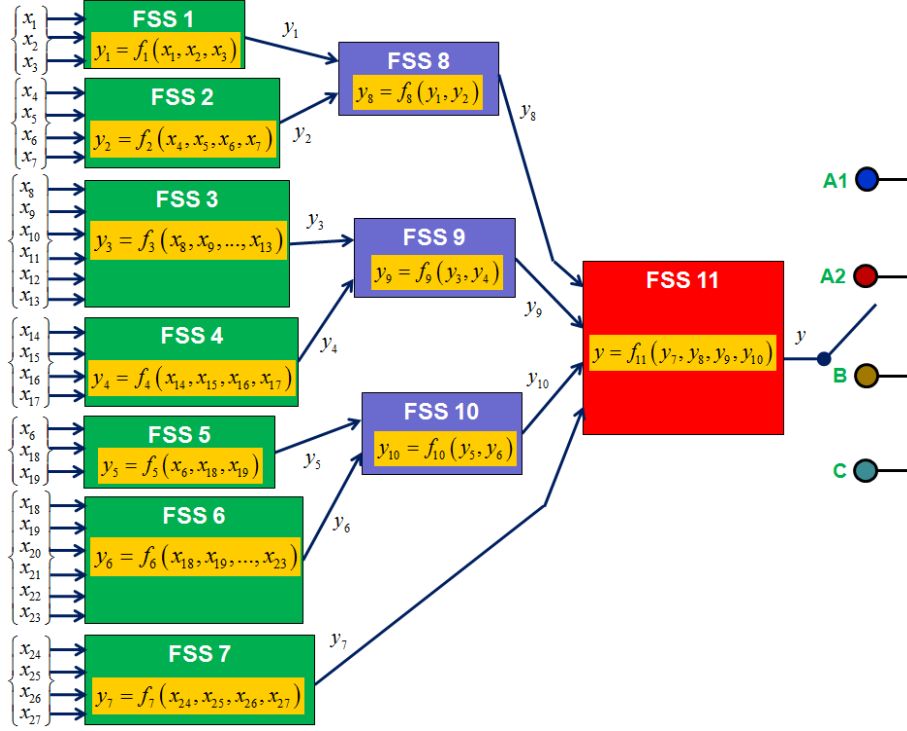
Creation of an effective network between academic and industrial partners is going to allow the higher education to reach modern specialist training formats which organically develop their theoretical and practical competence [1, 4-6].

## 2 Related Works and Problem Statement

Fuzzy model is meant to be an informational-logical model of a system which is based on the theory of fuzzy multitudes and fuzzy logic [11-13]. Therefore, the separate stages of fuzzy modelling are [14, 15]: analysis of problematic situation; structuration of a subject area and building of a fuzzy model; making a computing experiments with the fuzzy model; application of results of the computing experiments; correction or revision if the fuzzy model. Fuzzy techniques can be applied to solve different problems. In the paper [16] solved the problem of a fuzzy observer development for the clamping force automatic control system of a mobile robot. The paper [17] discusses the design of modern tactile sensor systems for intelligent (with fuzzy approach) and adaptive robots.

According to the latest research within various consortiums there has been proven that today effectiveness of cooperation depends on the cooperation model between university and industrial partners. Let's consider four ( $m = 4$ ) cooperation models as alternative decisions (solutions)  $E_i, (i = 1, \dots, m)$ . Herewith the model A1 corresponds to the decision  $E_1$  (cooperation between a university and a company to organize education and training, exchange of knowledge, purposeful training of the staff). Model A2 corresponds to the decision  $E_2$  (organization and support of the cooperation result certification processes). Model B corresponds to the decision  $E_3$  (creation of joint center of scientific research, development of joint scientific projects). Model C corresponds to the decision  $E_4$  (creation of scientific groups of students and independent business-oriented companies) [2-4, 7, 18].

The problem of selecting the cooperation model appears before a university in the beginning of a co-working and in conditions of altering the direction of development. Analysis of literature sources allows to mark emphasize on 27 main factors which influence on the selection of the model, particularly experience level of students, level of their involvement in international programs of exchange, experience level of company staff, education-qualification level of the company etc. [2, 4]. In the papers [18, 19] there were researched the problem of selecting of a model of cooperation and were built a system of fuzzy logic inference which is provided in Fig. 1. In this research, authors will lean on the given fuzzy inference system (FIS).



**Fig. 1.** DSS structure of cooperation model's selection

The authors developed the fuzzy intelligent DSS (Fig. 1) for choosing the rational model of cooperation of universities and IT companies [18, 19]. Corresponding DSS includes 27 input coordinates  $X = \{x_j\}, j = 1, \dots, 27$ , one output  $y$ , which are interconnected with fuzzy dependencies  $y_k = f(x_1, x_2, \dots, x_{27}), k = \overline{1, 11}$  of the relevant rule bases of 11 subsystems. Fig. 1 shows the version of proposed by the authors hierarchically-organized structure of DSS, which was formed from the decomposition of the input coordinate vector with their association to the group combination. In this case, the appropriate DSS subsystems (Fig. 1) in particular  $\{FSS_1, FSS_2, \dots, FSS_{10}, FSS_{11}\}$  implements the following functional dependencies for structure  $St = \{y_1, y_2, \dots, y_{10}, y\}$  of DSS [18, 19]:

$$St = \left. \begin{cases} y_1 = f_1(x_1, x_2, x_3), y_2 = f_2(x_4, \dots, x_7), y_3 = f_3(x_8, \dots, x_{13}), \\ y_4 = f_4(x_{14}, \dots, x_{17}), y_5 = f_5(x_6, x_{18}, x_{19}), y_6 = f_6(x_{18}, \dots, x_{23}), \\ y_7 = f_7(x_{24}, \dots, x_{27}), y_8 = f_8(y_1, y_2), y_9 = f_9(y_3, y_4), y_{10} = f_{10}(y_5, y_6), \\ y = f_{11}(y_7, y_8, y_9, y_{10}). \end{cases} \right\}$$

To evaluate the input coordinates  $X = \{x_j\}, j = 1, \dots, 27$  and intermediates  $y_8, y_9, y_{10}$  there were selected three linguistic terms (LTs) with triangular membership function (MF). Some of them:  $x_1$  is the level of scientific novelty of diploma (DP) and master's works (MW);  $x_2$  is practical significance of DP and MW;  $x_7$  is the success of students' learning;  $x_9$  is the number of patents;  $x_{10}$  is the number of grants;  $x_{11}$  is the level of scientific publications of the University Chair;  $x_{15}$  is the level of business course teaching;  $x_{16}$  is the experience in the organization of student companies;  $x_{19}$  is the staff experience level of IT companies;  $x_{20}$  is the education level of IT companies;  $y_9$  is the scientific and business level of the University Chair. To evaluate the intermediate coordinates  $y_1, y_2, y_4, y_5, y_7$  there were selected five LTs with triangular MF, including «low - L», «low than medium - LM», «medium - M», «higher than medium - HM», «high - H». Some of them:  $y_2$  is the level of professional orientation of students;  $y_4$  is the level of business orientation of the University Chair. To evaluate the intermediate coordinates  $y_3, y_6$  there were selected seven LTs with triangular MF, where  $y_3$  is the level of scientific activity of the University;  $y_6$  is the assessment of potential scientific and educational support level of the IT company. To evaluate the output variable  $y$  (the model of cooperation) there were selected four LTs with triangular MF, including «A1», «A2», «B», «C» [18, 19].

### 3 Fuzzy Approach for DSS's Design

Application of fuzzy multitude and fuzzy logic theory in design of DSS allows completing tasks on the intellectual level using expert knowledge bases [20-23].

An important problem of synthesis of DSS based on fuzzy logic inference is the complexity of making decisions with an altering input data structure of the system. This is related to the necessity of development of effective approaches to the correction of fuzzy knowledge bases. The necessity of corresponding correction or work-around of the rules, considering input signals, which are excluded from the vector of input coordinates during the selection of the person making decisions, appears in a certain application of the DSS in an interactive mode. In such interactive modes, the person can lower the dimensions of input coordinates of the DSS excluding the signals, which are the least important for the DSS and will not take part in the following process of making decisions [4, 19, 24-27].

Membership function (MF) represents the degree of membership of each element of a space to the given fuzzy multitude. More often, the membership functions from the Table 1 are used. In software application developed by authors, the following MFs were implemented: triangular and Gaussian (symmetrical) [24, 28, 29].

In fuzzy logic expressions more often as operators of intersection  $A \cap B$  (logical operator AND) various t-norms which define the form of implementation of a corresponding operation are used [25, 30].

**Table 1.** Membership functions

Name	Formula	Graphical representation
Triangular	$\mu(x) = \begin{cases} 0, & \text{when } x \leq a \text{ or } x \geq c \\ \frac{x-a}{b-a}, & \text{when } a < x \leq b \\ \frac{c-x}{c-b}, & \text{when } b < x < c \end{cases}$	
Gaussian (symmetrical)	$\mu(x) = e^{-\frac{(x-b)^2}{2c^2}}$	
Trapezoidal	$\mu(x) = \begin{cases} 0, & \text{when } x \leq a \text{ or } x \geq d \\ \frac{x-a}{b-a}, & \text{when } a < x \leq b \\ 1, & \text{when } b < x \leq c \\ \frac{d-x}{d-c}, & \text{when } c < x < d \end{cases}$	
Sigmoidal	$\mu(x) = \frac{1}{1 + e^{-a(x-c)}}$	

In the Table 2 there are represented some un-parameterized t-norm operators which were implemented by the authors in the software application [24, 25].

**Table 2.** Some un-parameterized t-norm operators

Name	Formula
Minimum (MIN)	$\mu_{A \cap B}(z) = \text{MIN}(\mu_A(x), \mu_B(y))$
Multiplication (PROD)	$\mu_{A \cap B}(z) = \mu_A(x) \cdot \mu_B(y)$

Defuzzification of a fuzzy multitude which is a result of an inference means an operation defining an accurate value  $y^*$  which would represent this multitude in the most rational way. There are different methods of defuzzification, the following are used

more often [24, 25]: method of an average maximum; method of the first maximum; method of the last maximum; method of the center of heaviness; method of the center of sums; method of altitudes.

Formally, Mamdani [31, 32] algorithm is implemented by the following stages.

*Stage 1.* Forming of knowledge bases of fuzzy logic inference system.

*Stage 2.* Fuzzification of input variables using membership functions of corresponding linguistic terms.

*Stage 3.* Activation of antecedents of rules.

*Stage 4.* Aggregation of antecedents of rules.

*Stage 5.* Accumulation of consequents (conclusions) of fuzzy rules.

*Stage 6.* Defuzzification of fuzzy multitude.

At the moment there exist a few pieces of software which allow to solve the problem of assessment and selection of cooperation model. The most popular ones are Fuzzy Logic Toolbox for the MatLAB packet and FuzzyTECH environment. The limitations of them are absence of some methods of aggregation and defuzzification, few membership functions, absence of discrete fuzzy logic inference [24, 33-35].

## 4 The Structure of Developed Computerized Intelligent DSS

The developed computerized intelligent DSS allows: to make more flexible setting of input parameters comparing to analogs, using existing methods of aggregation and defuzzification, to make logical inference in discrete and continuous forms [4, 24].

Authors should represent all (6 input, 2 intermediate and 1 output) linguistic variables (LVs) for the developed computerized intelligent DSS: “X1” is the level of professional orientation of students; “X2” is the level of business orientation of the university department; “X3” is the level of scientific activity of the university department; “X4” is the assessment of the possible exchange of knowledge among the personnel of the IT-company; “X5” is the assessment of the possible level of scientific support from the IT-company; “X6” is the assessment of the possible level of educational support from the IT-company; “Y1” is collaboration level of university; “Y2” is collaboration level of IT-company; “Y” is cooperation model.

Let’s review the structure and functions of the developed intelligent DSS for assessment and selection of the cooperation model in academia-industry cooperation on different combinations of settings, specifically, triangular and Gaussian MFs, t-norms MIN and PROD, and the MEAN operator [18, 24, 25, 36-39].

The process of creation of the first LV “X1” in the range [0, 50] with three LTs of triangular MF shown in Fig. 2. You can see three tabs in this figure. The first tab gives information about the name of the LV and its type. The second tab describes the variable in LTs. The third tab gives descriptive characteristic and comments of the current linguistic variable.

Thus was done 6 input LVs, 2 intermediate and 1 output variables. In the next step there was created a rules block (RB) (Fig. 3a). The window of rules for the first RB with LVs X1, X2 and X3 shown in Fig 3b.

The created computerized intelligent DSS shown in Fig. 4.

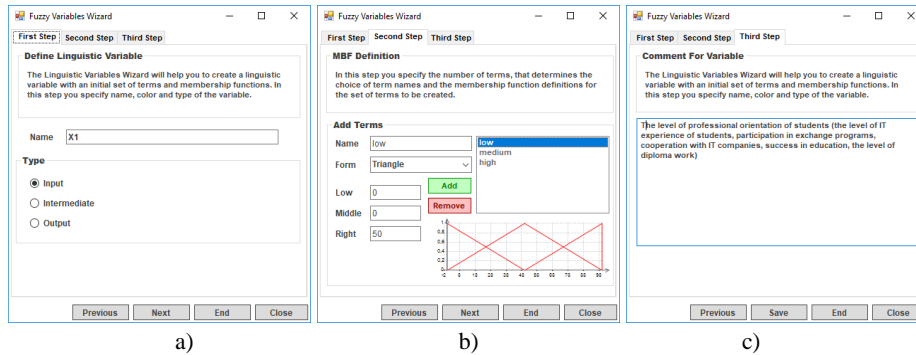


Fig. 2. Input LV “X1” (a) with 3 LTs: «low», «medium», «high» (b) and description with comments (c)

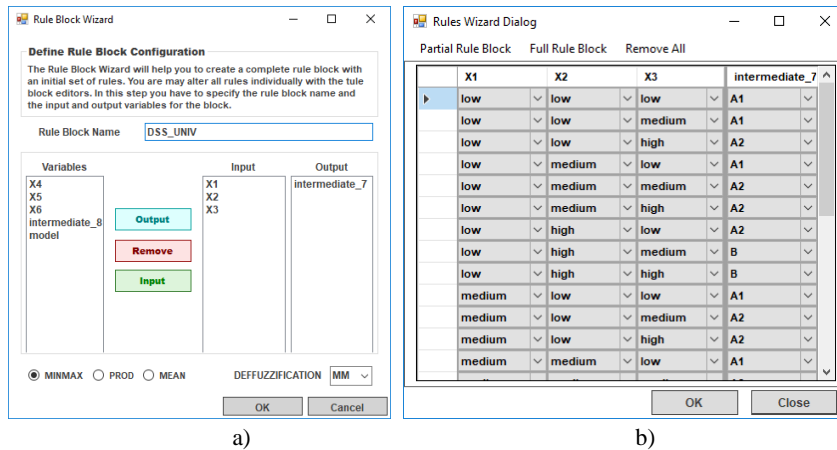


Fig. 3. Rules block wizard (a) and the window of rules for the first RB (b)

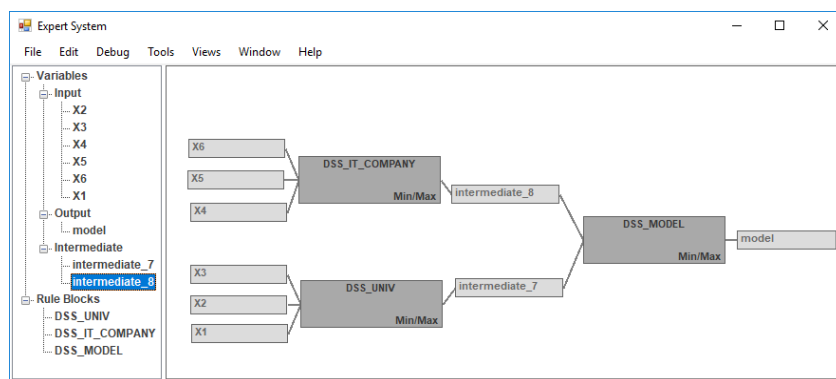
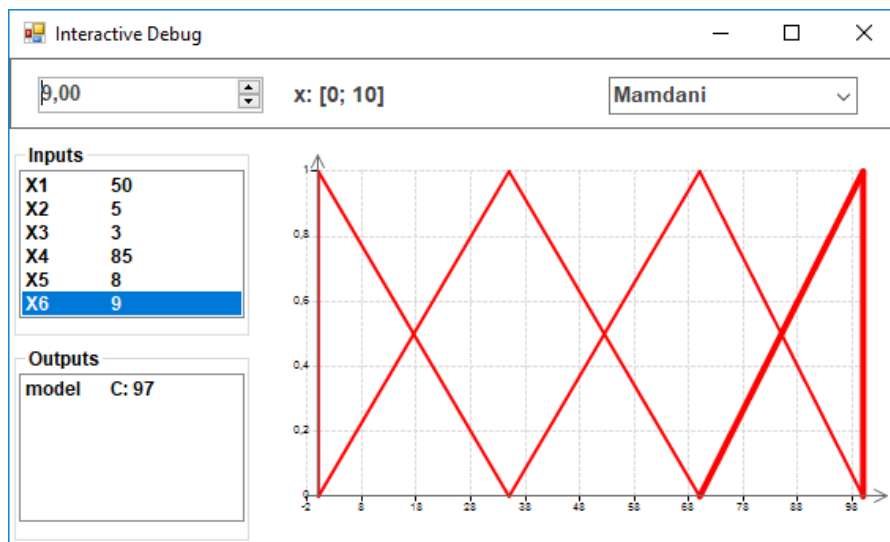
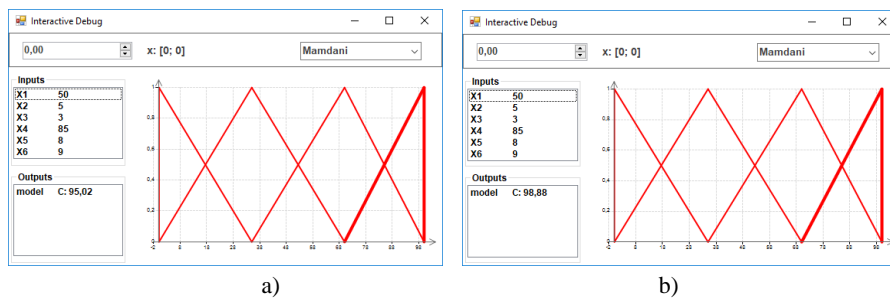


Fig. 4. The structure of created fuzzy DSS for cooperation model’s selection

After the launch of the system and input of the data ( $X_1 = 50$ ,  $X_2 = 5$ ,  $X_3 = 3$ ,  $X_4 = 85$ ,  $X_5 = 8$ ,  $X_6 = 9$ ) for our university and IT-company “ITServ”, the result of cooperation was computed as one of the models (A1, A2, B, C) in discrete and continuous forms of fuzzy inference engine (for example, model “C” with 97 points). It based on the Mamdani algorithm using the t-norm MIN (Fig. 5), t-norm PROD (Fig. 6a) and the MEAN operator (Fig. 6b).



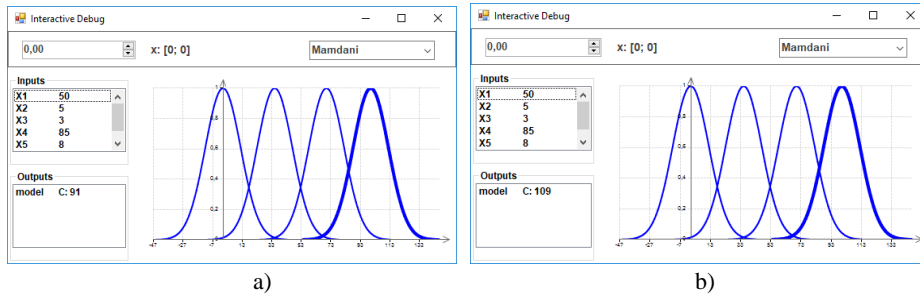
**Fig. 5.** The result of cooperation model’s selection using the t-norm MIN



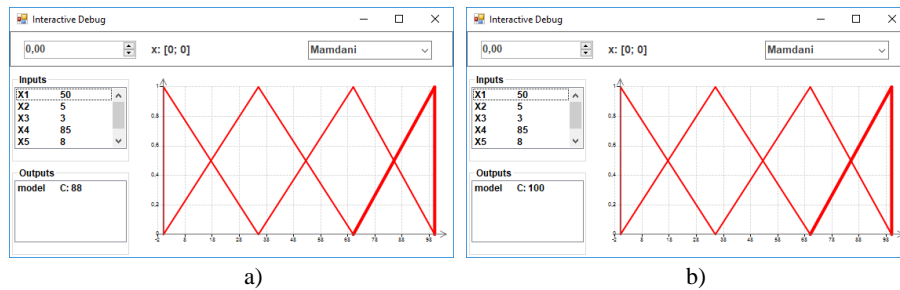
**Fig. 6.** Computing of cooperation model’s selection using the t-norm PROD (a) and the operator MEAN (b)

The results of research of the influence of changing the defuzzification method (left maximum and the right maximum methods) on the result of cooperation model’s selection while using the Gaussian (symmetrical) MF and the triangular MF are shown in Fig. 8 and Fig. 9. The corresponding variability allows expanding the functionality of the computerized system for cooperation model’s selection based on intelligent fuzzy technique [24, 40, 41].





**Fig. 8.** The result of cooperation model's selection with Gaussian (symmetrical) MF using the defuzzification method of left maximum (a) and the right maximum (b)



**Fig. 9.** The result of cooperation model's selection with triangular MF using the defuzzification method of left maximum (a) and the right maximum (b)

Therefore, the results of the developed computerized system show that using different membership functions, operators of t-norms, aggregation and defuzzification methods to solve the current task, the best cooperation model is model "C" (creation of scientific groups of students and independent business-oriented companies), but with different output values for further research and comparisons.

## 5 Conclusions

The authors developed a computerized system (DSS) for cooperation model's selection based on intelligent fuzzy technique, in particular, based on Mamdani-type fuzzy inference engine which allows: (a) more flexible settings for input signals, (b) the use of more wide row of existing methods for aggregation and defuzzification in fuzzy data processing, and (c) outputting results in both discrete and continuous forms. DSS's testing results for several real examples of academia-industry cooperation confirm the correctness and efficiency of cooperation model's selection. Developed based on C# software for intelligent DSS expands the functionality to research, analyze and solve the corresponding task of cooperation model's selection.

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