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Development of an intelligent learning system based on fuzzy logic

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Abstract. In modern institutions of higher education, the positive result of their work is measured by the progress of the student or by the factor how well the student meets the standard set by the state and the internal situation of the educational institution. In the current study, a new approach is proposed in assessing the progress of students, which is based on a fuzzy logic system. The proposed method uses three indicators: test tasks, written work and the possibility of mutual evaluation of students. Then, the quality of knowledge is assessed through the use of fuzzy logic, which is based on the Mamdani method. The results of applying this approach show that the proposed method can have practical application in assessing the quality of students' progress.

1. Introduction

The educational system, which is an actual field of activity, is determined by the high complexity of modeling the environment through mathematical expressions and the dynamics of variables, which greatly complicates the correlation process. The traditional form of interaction between a teacher and a student is still a verbal (informal) form. Over time, it will be possible to interpret human judgments in mathematical models, the description of which will take place in a natural, for a person, language, which will be based on fuzzy sets, with the help of which vague, divergent and incorrect criteria will be determined. The basis of the model of human actions and choices is well defined by fuzzy logic; this method is easily integrated into automated decision support systems. Using a mathematical model to build fuzziness in the initial information component, it will make it possible to obtain results that are adequate to reality.

In educational institutions, a positive result is determined by the student's academic performance or how well the student meets the established state educational standards. As the competition for careers becomes more intense every day, the importance of students doing well in all areas has attracted widespread public attention [1-8].

Educational assessment is a process in which learning outcomes are recorded, primarily in terms of measurable indicators of knowledge based on the use of certain criteria. Such an assessment can be defined as a measure of skills, attitudes and beliefs.

In order to effectively apply the fuzzy set in the field of education, many efforts have been made to determine an effective model. The purpose of the proposed method is to offer a new approach to the existing student assessment system.



2. Related work

To determine the relevance and effectiveness of the use of fuzzy logic in educational activities, a number of works were analyzed.

Troussasa et al. [9] developed and implemented an intelligent educational mobile application based on Quiz Time! to assess the level of knowledge of students based on a fuzzy logical model. The app includes a student assessment module, a vector-based personalized team game collaboration recommendation module, and a dynamic advice generator that uses fuzzy logic to help learners learn the C # programming language. The experiment involved 20 computer scientists and 80 undergraduate students of the Faculty of Informatics, the results confirmed the pedagogical adequacy of the application, its positive impact on learning and usefulness.

Under the guidance of Na Li [10], a recommendation model of fuzzy logic based on the fuzzy learning model (RGEL-FL) is proposed to assess the learning style, the level of the learning class and the degree of satisfaction from the training of engineering students. Data analysis based on the results of the study allowed us to build a logical model based on fuzzy logic and develop online training courses in order to activate the independent work of students. The approbation of the model allowed the authors to implement training, taking into account the individual preferences and capabilities of the student. The effectiveness, quality and accuracy of the training model are proved by taking into account the characteristics of a separate class of participants with the same preferences, their potential in a personalized educational environment. The proposed RGEL-FL method provides high efficiency.

In their study, F. Tugrul and M. Citil [11] applied the PROMETHEE multi-criteria decision making method (MCDM) using intuitionistic fuzzy set (IFS) to determine the ranking of school performance and select the most successful school depending on certain criteria. The students' GPA on the official exam was calculated and a grade point was awarded for each school. The official exam consisted of six core lessons. Thus, the criteria defined such basic lessons as Turkish, mathematics, science, social studies, English, religion. Simultaneous consideration of both intuitionistic fuzzy sets and criterion weights made it possible to obtain more consistent and rational results. The advantage of the PROMETHEE method lies in the assessment taking into account the criterion weight. The weight of the criteria shows how important they are. Through the use of the intuitionistic fuzzy method PROMETHEE, the success of the schools was assessed based on student achievement, and the most successful school was selected. The application can be used in cases where it is necessary to make a choice among alternatives based on a variety of criteria.

T. Aol et al. [12] developed an initiative-systematic assessment of the effectiveness (I-SPE) of leadership quality measurements based on the fuzzy logic approach. The study analyzed data within the framework of the leadership program - the Kepimpinan Pewaris Bangsa (PKPB) program conducted at the Universiti Teknologi MARA (UiTM) for highly rated students. The fuzzy logic apparatus was used to make decisions and evaluate the effectiveness of the approach in order to eliminate uncertainty and exclude the subjectivity of evaluating expert opinions. The authors proposed a model based on the production rules according to the criteria: leadership, communication, teamwork, discipline and the total average score for all criteria. The results obtained show that the proposed decision-making system makes it possible to fairly select the best candidate in comparison with the traditional method.

3. Methodology

A hybrid intelligent system has been designed to conduct research. This system is integrated into the teaching methodology of undergraduates of Orenburg State University and allows you to model the educational route of a particular student, taking into account his individual needs. For example, it is proposed to evaluate the overall level of mastering the discipline by means of the author's developed system based on the mathematical apparatus of fuzzy logic. For multidimensional models, decomposition operations are used, which allow dividing the model into many particular fragments of the model and conducting a complete analysis of the research area. The applied problem is solved by using the composition of the model on a fragment. In various applied subject areas that work in optimal or extreme situations, it may be necessary to make a decision in conditions of fuzziness, uncertainty,

unreliability of time and resource constraints. The developed solution allows, based on the above factors, through the apparatus of methods and means of implementing dynamic interacting processes operating under conditions of uncertainty, to build a data management and processing system and offer an optimal solution.

Due to the high relevance of the parameter for evaluating the results of students, two types of control are proposed for the teacher: testing of students and conducting written control works.

Test indicators are achieved based on the objectivity of the measurement process and the interpretation of the results.

During the implementation of written control works, the teacher often treats subjectively or ambiguously to the subject of assessment. The implementation of the competence approach can provide an opportunity to solve such a problem. Such a decision implies a change in the way of assessment by means of a meaningful and criteria-based assessment of learning outcomes. A detailed study of the evaluation criteria (performance criteria) allows you to perform an unbiased procedure for evaluating learning indicators. The developed evaluation criteria are a list of the types of student's activities that he performs in the course of his educational activities, as well as optimal performance criteria. With such an implementation of the educational process, the subjectivism of the teacher is absolutely excluded or manifests itself to a small extent.

The values at the output of the variable "A.Test" (Testing of students) have the following input variables: a_1 – assessment of testing on topic 1; a_2 – assessment of testing on topic 2; ...; a_n – assessment of testing on topic n.

Let's define the indicators of the output variable "B.Teacher": in it, the teacher gives an assessment of the completed task according to the developed criteria for each topic: b_1 – assessment for the task on topic 1; b_2 – assessment for the task on topic 2; ...; b_n – assessment for the task on topic n.

In the output variable "C.Student": students themselves evaluate the work of their colleagues according to the proposed criteria: c_1 – evaluation of work on topic 1; c_2 – evaluation of work on topic 2; ...; c_n – evaluation of work on topic n.

In each variable ("A.Test", "B.Teacher" and "C.Student") determines the weight (significance) of the integral assessment. Component "B.Teacher" should have a higher significance index than other components, since the teacher is an expert in the subject area in terms of the discipline being taught. Therefore, it is advisable to set the following weight coefficients: "Test control" – 0,3; "Teacher" – 0,5; "Student" – 0,2.

The developed comprehensive solution for assessing the level of mastery of the discipline allows you to use a mathematical model associated with fuzzy sets and fuzzy logic. Such a solution is necessary when obtaining a result in conditions of limitation and fuzziness. A higher level of detail can lead to a reduction in the volume of processed and stored large amounts of data and to an increase in the performance of algorithms.

4. Mathematical model

According to Mamdani's algorithm, fuzzy logical inference is performed on a fuzzy knowledge base:

$$\bigcup_{p=1}^{k_j} (\bigcap_{i=1}^n x_i = a_{i,jp} \text{ with weight } w_{jp}) \rightarrow y = d_j, \quad (1)$$

in which the values of the input and output variables are given by fuzzy sets. We introduce the following notation necessary for further presentation of the material:

$\mu_{jp}(x_i)$ - function of the input belonging to a fuzzy set $a_{i,jp}$, i.e.:

$$a_{i,jp} = \frac{\int_{x_i}^{\bar{x}_i} \mu_{jp}(x_i)}{x_i}; \quad (2)$$

$\mu_{dj}(y)$ - function of the output belonging to a fuzzy set d_j i.e.:

$$d_j = \frac{\int_y \mu_{d_j}(y)}{y}. \quad (3)$$

The degree of membership of the input vector in which

$$x^* = (x_1^*, x_2^* \dots, x_n^*) \quad (4)$$

belongs to fuzzy sets of d_j from the accumulated knowledge base, the calculation of this function is as follows:

$$\mu_{d_j}(X^*) = V_{p=1, k_j} w_{jp} \cdot \bigwedge_{i=1, n} [\mu_{jp}(X_i^*)]. \quad (5)$$

An operation from the s-norm (t-norm), i.e. from a set of implementations of logical operations OR (AND). Implementations are most often used: when performing the operation OR, the maximum is found, when performing the operation AND, the minimum is found.

As a result, we obtain such a fuzzy set y corresponding to the input vector x^*

$$y = \frac{\mu_{d_1}(X^*)}{d_1} + \frac{\mu_{d_2}(X^*)}{d_2} + \dots + \frac{\mu_{d_m}(X^*)}{d_m}. \quad (6)$$

The peculiarity of this fuzzy set is that the universal set for it is the set of the output variable y .

5. Practical part

Based on the results of a comprehensive assessment, as well as their interpretation (Table 1), a dynamic adjustment of the individual educational trajectory and the introduction of an intelligent system of recommendations is possible [13].

Table 1. Range of integrated assessment values.

The end result	Rating 'not satisfactory'	"Satisfactory" rating	Rating "good"	Rating "very good"	Rating "excellent"
Result	0-49	50-64	65-74	75-84	85-100

Let's consider the stages through which the results of mastering the discipline and making a comprehensive decision are evaluated under the condition of uncertainty in the developed fuzzy model.

1. Introduction of fuzziness on the initial range of values "A.Test", "Y.Instructor" and "C.Student", as well as the "output" value of "Result". With the introduction of fuzziness, the model transitions from a numerical indicator to a symbolic fuzzy value.
2. Writing rules by means of which the fuzzy inference algorithm will be applied using logical operations of union and intersection.
3. Representation of a fuzzy set of results obtained by a clear number in the value "Result".

In figure 1 shows a scheme for evaluating the results of students, based on the use of a fuzzy model.

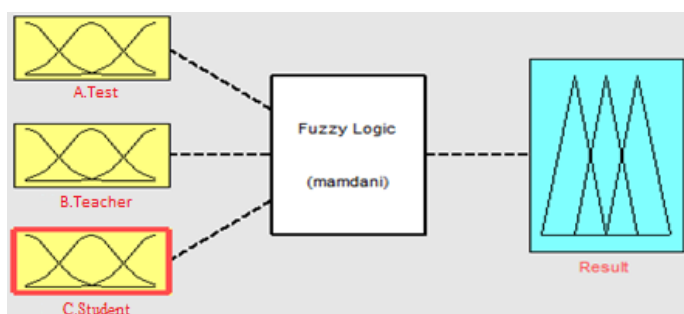


Figure 1. Scheme definition of evaluation of students' results.

Having conducted an experiment based on the developed course "Modern Tools", the structure of which is represented by five topics, it became possible to obtain a sets for each linguistic variable we are interested in.

When carrying out the developed testing method, it was decided to use a hundred-point scale for evaluating the results of mastering, the selected range of which is presented in table 2.

Table 2. A set of values in the variable "A.Test".

Final Result (Output)	Rating "Unsatisfactory"	Rating "Satisfactory"	Rating "Good"	Rating "Excellent"
A. Test	0-59	60-75	76-89	90-100

To facilitate the evaluation of test results for the teacher, certain evaluation criteria have been compiled for each group of tasks and in each topic.

Further, in accordance with the criteria obtained, scores were set and levels were identified (table 3). By analogy, students themselves evaluate the work of their colleagues.

Table 3. Values of sets "B.Teacher" and "C.Student».

Final Result	Rating "Unsatisfactory"	Rating "Satisfactory"	Rating "Good"	Rating "very good"	Rating "Excellent"
B. Teacher/C. Student	0-49	50-64	65-74	75-84	85-100

Rules are defined by membership functions, which are based on the results of input and output values. The developed rules are called linguistic. An example of the developed rule base is shown in figure 2.

1. If A.Test is Unsatisfactory and B.Teacher is Unsatisfactory and C.Student s is Unsatisfactory then Result is Poor
2. If A.Test is Unsatisfactory and B.Teacher is Unsatisfactory and C.Student is Satisfactory then Result is Poor
3. If A.Test is Unsatisfactory and B.Teacher is Unsatisfactory and C.Student is Very Good then Result is Average
4. If A.Test is Excellent and B.Teacher is Excellent and C.Student is Excellent then Result is Excellent
5. If A.Test is Good and B.Teacher is Very Good and C.Student is Very Good then Result is Very Good

Figure 2. Rule base.

The results of applying fuzzy logic using a rule base are shown in figure 3.

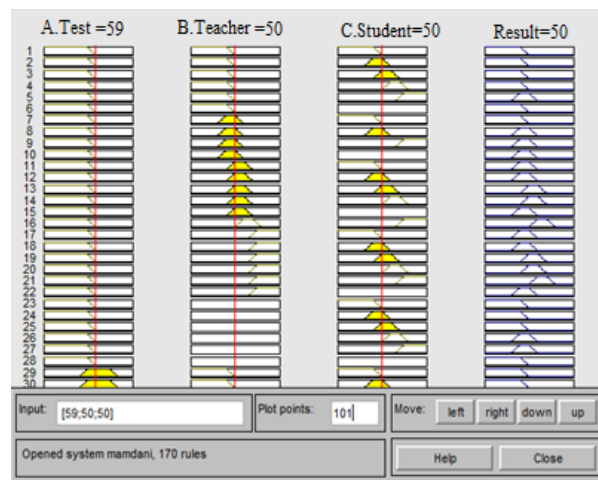


Figure 3. Results of applying fuzzy logic using a rule base.

6. Conclusion

In the presented work, a software package was used in the MATLAB environment, which contains functions for working with fuzzy logic, allowing you to build a logical inference model. In the work, three inputs were designed to set the initial range of values, which send a set of values through the processing module. The output of the results occurs at one output. The approbation of the developed model took place on different groups of students. The accuracy of the results is 95%. The developed model, based on the fuzzy logic method, allows:

- more accurately assess the level of training of students and the level of assimilation of the discipline;
- determine the most optimal input variables and set the most acceptable linguistic criteria;
- rebuild the developed model to meet different requirements and goals.

Further research involves the expansion of criteria and variables for more accurate analysis, as well as the introduction of this model into the system of online courses.

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