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Decision Support in Problems of Course Selection During Personalization of Learning Based on the Fuzzy Logic Method

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Abstract. *The article is devoted to the actual problem of designing information systems for automated selection of courses using fuzzy logic, which take into account the personal characteristics of students. As part of the study, a decision-making system was implemented through the educational platform of personalized learning to determine the compliance of elective course packages. Elective courses developed as content for this platform are conditionally divided into 4 packages, reflecting certain personal characteristics of students. The system offers students the most suitable package of courses. Within the framework of the article, a model of fuzzy inference is described and a base of production rules is presented.*

Keywords: *fuzzy logic, production rule base, software implementation, MATLAB, course package, personal characteristics, personalization, elective courses.*

Introduction

Currently, personalized learning approaches are discussed in the scientific community mainly in the context of the development of distance learning technology, individualization and differentiation of learning. Among foreign scientists, the works of Canales Cruz A., Pena-Ayala A. (development of a web-based education system focused on the learning needs of an individual student) [1], Worsley D., Fox E., Landzberg J., Papagiotas A. (personalization of high school students' learning through shift groups) [2], Wilson S. (design personal learning environments) [3], Martin M. (personalized learning as a means of professional development) [4], A.A. Vlasenko (development of an adaptive distance learning system, creation of a student model for an adaptive learning system) [5].

Such Russian scientists as E.Y. Bidaibekov, D.N. Isabayeva, N. Oshanova, V.V. Grinshkun, G.B. Kamalova, B.G. Bostanov (the use of modern information and communication technologies in teaching) made a great contribution to the development of the information learning environment and applied ideas of personalization and individualization [6], G.G. Yerkibayeva (homogeneous groups as the basis of differentiated learning) [7], I.O. Saifurova (personalization as a tool for developing programming skills) [8], N.V. Savina, N.K. Omarbekova (e-learning courses as a means of personalization in medical institutions) [9], Zh. Seitakhmetova (application mobile technologies in universities with personification of learning) [10], G.Bekmanova (model of learning in personification conditions) [11], etc.

Scientific and practical research in the field of personalization of learning reveals the technical aspects of this problem through the introduction of the concept of "Information and communication educational environment" (hereinafter ICOS) as "a set of objects of the educational process (content, forms, methods, means of teaching and educational communications) based on information technology, with variable characteristics, providing the subjects of the educational process (trainee, teacher) the possibility of designing educational and cognitive activity" [12].

The study "Reimagining the Role of Technology in Education" (2017) fully reveals the importance of integrating information educational technologies in the context of personalized learning [13]. In higher educational institutions, research is being conducted and significant projects are being implemented aimed at developing the personalization of training using modern platform solutions in which cadets determine their level of primary competencies and implement their own development trajectory. The main assistant in these projects is artificial intelligence. A striking example is the published works, which offer various solutions regarding personalization technologies in e-learning systems. These include the work [14] devoted to an agent-based approach to developing a system of recommendations for improving learning skills and simplifying the choice of courses in accordance with the interests and preferences of users. These studies, aimed at using the technological advantages of e-learning and improving its quality, have become acutely in demand in the context of the pandemic limitations of COVID-19. The papers propose various solutions regarding personalization technologies in e-learning systems of higher education, while the application of these approaches in school education remains unexplored. Based on the urgency of this problem, there is a need to create an automated decision support system for selecting courses based on personal characteristics. Due to the fact that the input data for making a decision taking into account personal characteristics are fuzzy, the decision itself is also fuzzy. Therefore, in this case it is appropriate to use the fuzzy logic apparatus: to build a model of a fuzzy inference system, create a base of fuzzy production rules and present their software implementation. These aspects are the purpose of the research within the framework of this article.

Research methodology

The fuzzy logic method was used to conduct the study. The model of the decision support system was designed on the basis of fuzzy sets and fuzzy inference using the Mamdani algorithm. Aggregation of the sub-conditions of the fuzzy production rules was carried out using the classical fuzzy logical operation "And" two elementary statements A, B: $T(A \cap B) = \min\{T(A);T(B)\}$.The development of a database of production fuzzy rules is an interactive process, therefore, the study used the method of expert assessments before checking the operation of the system in real conditions.

Results

The task is to develop a model of a fuzzy inference system in which the output parameter is a decision of a recommendatory nature on the choice of a certain package of courses for students. The model of the fuzzy inference system is shown in Figure 1.

The model of the fuzzy inference system proposed above is represented by a set of rules for fuzzy output, according to well-known principles [15, p. 13].

The kernel of the fuzzy product A ≥ B is written as follows:

IF X is A, then Y is B,

X is the domain of definition of the antecedent of the fuzzy rule;

A is a fuzzy set defined on X;

Y is the area of definition of the fuzzy rule consequence;

B is a fuzzy set defined on Y [15, p. 15].

According to the fuzzy inference model, input parameters (variables X_1, X_2, X_3) and output parameters (variable Y) are defined for the formation of rules for assessing the compliance of the course with the personal characteristics of the student. In this problem, the input parameters are taken into account not in an exact measurement, but in a certain range of values with corresponding linguistic terms:

- Variable X_1 = "Level of current knowledge on the subject" with a universal set $U(X_1) = [0,1]$. Term-set $T(X_1)$ = {"high", "threshold", "low"}.

- Variable X_2 = "English proficiency level" with a universal set $U(X_2) = [0,1]$. Term-set $T(X_2)$ = {"above average", "average", "basic"}.

- Variable X_3 = "Digital competence level" with a universal set $U(X_3) = [0,1]$. Term set $T(X_3)$ = {"advanced", "confident", "average"}.

In this case, the decision on the compliance of the proposed package of courses with the personal characteristics of the student is also a fuzzy value Y:

The variable Y = "The indicator of compliance of the package of courses with the personal characteristics of the student", with a universal set $U(Y) = [0,1]$. Term set $T(Y)$ = {"package 1", "package 2", "package 3", "package 4"}.

The package of courses (structure and con-

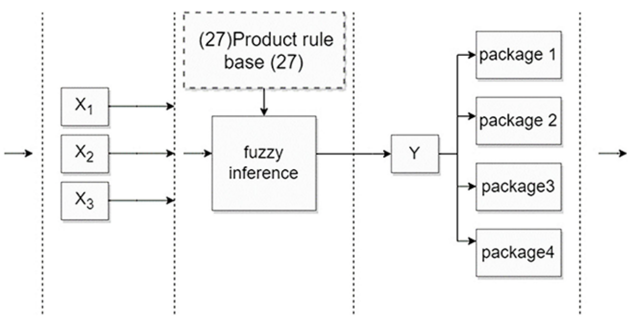

Figure 1 – Model of the fuzzy inference system

tent of programs) is formed by a teacher (tutor) who has undergone special training, and is evaluated by an expert in terms of 3 parameters:

1. What level of input knowledge on the subject is the course focused on: high, threshold, low.
2. At what level of English language proficiency is the course based: above average, intermediate, basic.
3. What is the minimum level of digital competencies required to master the course: advanced; confident; average.

Table 1 shows the general interpretation of the evaluation scale of each variable, determined by experts.

The membership functions for the variable X_1, reflecting the stage of the process, have the following form:

$$\mu^{\text{High}}(x) = (0.8, 0.9, 1, 1),$$
$$\mu^{\text{Threshold}}(x) = (0.4, 0.6, 0.8, 0.9),$$
$$\mu^{\text{Low}}(x) = (0, 0, 0.4, 0.6),$$

shown in figure 2.

The membership functions for the variable X_2 have the following form:

$$\mu^{\text{Above average}}(x) = (0.65, 0.7, 1, 1),$$
$$\mu^{\text{Medium}}(x) = (0.3, 0.35, 0.65, 0.7),$$
$$\mu^{\text{Basic}}(x) = (0, 0, 0.3, 0.35).$$

The membership functions of the terms of the input variable X_2 are shown in Figure 3.

The membership functions for the variable X_3, reflecting the level of digital competencies, have the following form:

$$\mu^{\text{Advanced}}(x) = (0.7, 0.8, 1, 1),$$
$$\mu^{\text{Confident}}(x) = (0.55, 0.65, 0.7, 0.8),$$
$$\mu^{\text{Average}}(x) = (0, 0, 0.55, 0.65).$$

The membership functions of the terms of the input variable X_3 are shown in Figure 4.

The membership functions for the output variable Y, reflecting the recommendations for choosing the appropriate course package, have the following form:

$$\mu^{\text{package4}}(y) = (0.65, 0.7, 1, 1),$$
$$\mu^{\text{package3}}(y) = (0.45, 0.5, 0.65, 0.7),$$
$$\mu^{\text{package2}}(y) = (0.3, 0.39, 0.45, 0.5),$$
$$\mu^{\text{package1}}(y) = (0, 0, 0.3, 0.39).$$

The membership functions of the terms of the output variable Y are shown in Figure 5.

This study is based on the Mamdani algorithm. Fuzzy inference according to the Mamdani algorithm is carried out according to the knowledge base according to the formula (1):

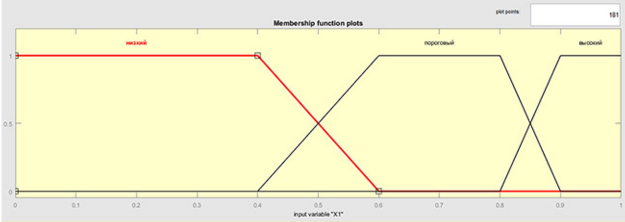

Figure 2 – Membership functions of the terms of the input variable X_1

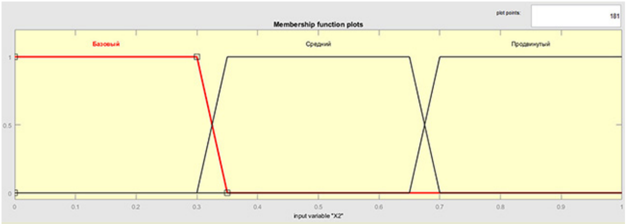

Figure 3 – Membership functions of the terms of the input variable X_2

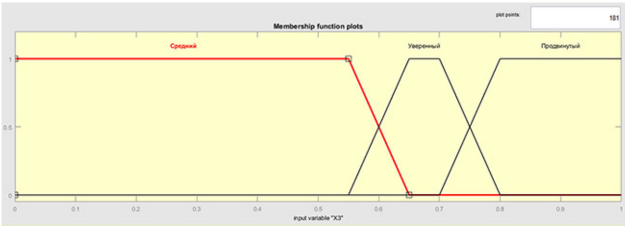

Figure 4 – Membership functions of the terms of the input variable X_3

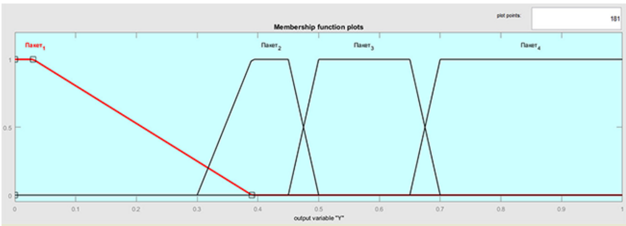

Figure 5 – Membership functions of the terms of the output variable Y

$$\begin{aligned}(x_1 = \tilde{a}_1 \theta_j x_2 = \tilde{a}_{2j} \theta_j \ldots \theta_j x_n = \\ = \tilde{a}_{nj} \text{ with weight } w_j) \Rightarrow y = \tilde{d}_j,\ \ j = \overline{1,m}\end{aligned} \quad (1)$$

The next step was to remove the combination of meaningless antecedents. The consequences were set with the participation of an expert. Thus, the developed database of rules for assessing the compliance of the course package with the personal characteristics of the student contains 27 products and is presented in Table 2.

Table 1 – Characteristics of the assessment scale

Variables	Characteristics of the assessment scale			Max. meaning
	High	Threshold	Low	
X_1	Demonstrates deep knowledge and understanding of subject concepts, performs complex tasks, successfully applies knowledge in various situations	Demonstrates sufficient knowledge and understanding of subject concepts, performs typical tasks, successfully applies knowledge in familiar situations	Demonstrates elementary knowledge and understanding of subject concepts, performs simple tasks, applies knowledge in accordance with direct instructions	100%
X_2	Above average/competent knowledge, course without support/	Medium//moderate knowledge, a course with an interactive dictionary/	Basic/limited knowledge, course with simultaneous translation/	7 points
X_3	Advanced/knows, successfully applies and can teach/	Confident/knows and applies most of the tools and methods/	Average/knows and applies some tools and techniques/	10 points

Table 2 – Rule base

№	Operation	Level of current knowledge (X_1)	Level of foreign language proficiency (X_2)	Level of digital competencies (X_3)	Recommended course package (Y)
1	AND	High	Advanced	Advanced	Package 4
2	AND	High	Advanced	Confident	Package 4
3	AND	High	Advanced	Average	Package 3
4	AND	High	Average	Advanced	Package 4
5	AND	High	Average	Confident	Package 4
6	AND	High	Average	Average	Package 3
7	AND	High	Basic	Advanced	Package 3
8	AND	High	Basic	Confident	Package 3
9	AND	High	Basic	Average	Package 2
10	AND	Threshold	Advanced	Advanced	Package 4
11	AND	Threshold	Advanced	Confident	Package 4
12	AND	Threshold	Advanced	Average	Package 3
13	AND	Threshold	Average	Advanced	Package 4
14	AND	Threshold	Average	Confident	Package 3
15	AND	Threshold	Average	Average	Package 3
16	AND	Threshold	Basic	Advanced	Package 2
17	AND	Threshold	Basic	Confident	Package 2
18	AND	Threshold	Basic	Average	Package 2
19	AND	Low	Advanced	Advanced	Package 2
20	AND	Low	Advanced	Confident	Package 2
21	AND	Low	Advanced	Average	Package 2
22	AND	Low	Average	Advanced	Package 1
23	AND	Low	Average	Confident	Package 1
24	AND	Low	Average	Average	Package 1
25	AND	Low	Basic	Advanced	Package 1
26	AND	Low	Basic	Confident	Package 1
27	AND	Low	Basic	Average	Package 1

The software implementation of these rules in Matlab is shown in Figure 6.

Figure 7 shows the surface of the fuzzy model for the production rules base, implemented in the MATLAB environment.

The constructed model makes it possible to determine the output value of the variable Y from the given values of the input variables.

Conclusion

Thus, in this study, a production model for assessing the compliance of a package of courses with individual characteristics of students has been developed and 27 production rules have been defined. The presence of a system for automatically selecting a package of training courses based on a fuzzy logic model that takes into account the personal characteristics of students will be a distinctive feature of information technology to support personalized learning. The proposed model can be used as the basis for the system of organization of the educational process of the senior classes of secondary schools in the distribution of training profiles and within the effective distribution of the variable component of the curriculum.

Appreciation

The research was carried out within the framework of state funding under the scientific project No. 137-460-23 dated August 3, 2023 AP19680002 "Methodology for the formation of digital identity of students in the continuous education circuit in universities of the Republic of Kazakhstan".

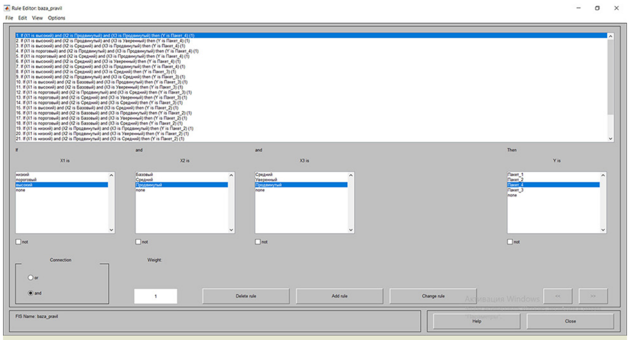

Figure 6 – Software implementation of the rule base

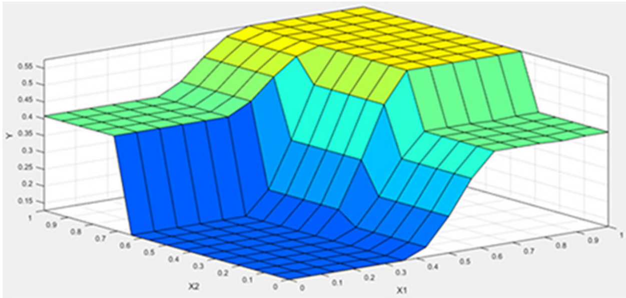

Figure 7 – Surface of the fuzzy model for the rule base

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Анық емес логика әдісі негізінде оқытуды дербестендіру кезіндегі пәнді таңдау мәселелеріндегі шешімдерді қолдау

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Аңдатпа. *Мақала анық емес логиканы пайдалана отырып, білім алушылардың жеке сипаттамаларын ескеретін курстарды автоматты таңдау үшін ақпараттық жүйелерді жобалаудың өзекті мәселесіне арналған. Зерттеу аясында элективті курс пакеттерінің сәйкестігін анықтау үшін дербестендірілген оқытудың білім беру платформасы арқылы шешім қабылдау жүйесі жүзеге асырылды. Осы платформаның мазмұны ретінде әзірленген элективті курстар білім алушылардың белгілі бір жеке сипаттамаларын ескеретін 4 пакетке шартты түрде бөлінген. Мақала аясында анық емес логика моделі сипатталған және продукциялық ережелер базасы ұсынылған.*

Кілт сөздер: *анық емес логика, продукциялық ережелер базасы, бағдарламалық қамтамасыз етуді енгізу, MATLAB, курстар пакеті, жеке сипаттамалар, дербестендіру, элективті курстар.*

Поддержка принятия решений в задачах подбора курсов при персонализации обучения на основе метода нечеткой логики

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Аннотация. *Статья посвящена актуальной проблеме проектирования информационных систем автоматизированного подбора курсов с использованием нечеткой логики, в которых учтены персональные характеристики обучающихся. В рамках исследования осуществлено внедрение системы принятия решения через образовательную платформу персонализированного обучения для определения соответствия пакетов элективных курсов персональным данным. Элективные курсы, разработанные в качестве контента к данной платформе, условно разделены на 4 пакета, отражающие те или иные персональные характеристики учащихся. Система предлагает учащимся наиболее подходящий пакет курсов. В рамках статьи описана модель нечеткого вывода и представлена база продукционных правил данного решения.*

Ключевые слова: *нечеткая логика, база продукционных правил, программная реализация, MATLAB, пакет курсов, персональные характеристики, персонализация, элективные курсы.*

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