A Fuzzy System for the Quality Assessment of Educational Multimedia Edition Design

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Article

A Fuzzy System for the Quality Assessment of Educational Multimedia Edition Design

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Abstract: The quality of educational multimedia edition design is determined by a set of characteristics that affect perception, readability and communication efficiency. Predicting the quality of multimedia edition design is based on a comprehensive analysis of characteristics that affect the aesthetics, functionality and adaptability of a multimedia product. Within the framework of this study, the goal is to develop a fuzzy system for predicting the quality of educational multimedia edition design. An approach to determining an integral quality indicator based on fuzzy logic is proposed, which ensures that the influence of various factors that cannot be characterized exclusively by numerical parameters is taken into account. A multilevel model of fuzzy logical inference is constructed, representing the hierarchical dependency between quality factors. Membership functions for linguistic variables are formed and their weight coefficients are determined using pairwise comparison matrices. The developed approach contributes to making informed management decisions in the process of creating multimedia products. The use of fuzzy logic methods allows one to assess the design quality even under conditions where the parameters are subjective or do not have clear numerical characteristics. Thus, quality prediction provides the opportunity to identify the design weaknesses at the stage of its development, optimize the process of creating multimedia editions and increase the efficiency of their use in educational and professional environments. Further research aimed at integrating artificial intelligence for automated updating of the knowledge base and expanding the system by introducing additional assessment criteria is considered to be promising.

Keywords: educational multimedia edition, fuzzy logic, fuzzy system, fuzzification, defuzzification, predictive quality assessment

1. Introduction

The rapid development of technologies, competition and constantly growing demands of readers contribute to the development and digitalization of the book market [1]. Educational multimedia editions as complex information products that integrate text, graphic, audio and video content into a single structure, ensuring interactivity and multi-channel information transmission are becoming increasingly popular. Multimedia editions can be considered as an innovative form of traditional printed media, adapted to modern technologies and the needs of a digital society [2–3]. As a rule, they preserve the structural organization of a book, expanding its functionality. This contributes to the accessibility of digital educational platforms and the development of educational programs.

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A feature of multimedia products is the ability to adapt the content to the individual needs of users thanks to interactive tools, availability on different platforms and the possibility of constant information updating [4]. Such technologies are often used in the field of education [4, 5], science [6], art [7] and business [8] as an effective means of knowledge transfer. It is extremely important that the use of multimedia editions contributes to increasing the efficiency of the educational process due to the adaptability of the material to the needs of knowledge seekers [4]. At the same time, the quality of the educational edition design plays a key role in interaction with users [9–11]. The lack of a theoretically sound methodology for the quality assessment of the educational multimedia edition design complicates analytical studies aimed at determining the multimedia impact on the quality of learning and ease of material understanding.

Inconsistent, chaotic execution of operations aimed at the design of educational multimedia editions and the lack of understanding of the relationships between them leads to the impossibility of predicting the final result, which undoubtedly negatively affects the quality of the resulting product and, accordingly, the quality of the educational process [12]. Another problem is that developers of multimedia editions often direct their main efforts to technological implementation, neglecting editorial and publishing processes. It is a misconception that only printed editions require editorial processing. High-quality presentation of content, in addition to layout, illustrative, multimedia, font design, also requires consideration of such parameters as: recommended size of the edition format; the edition complexity, which is determined by its type; the edition volume, which directly affects the complexity of proofreading, etc. [13, 14].

The studies [15, 16] indicate the need for implicit (non-verbal) assessment of linguistic variables, the meaning of which is initially presented as a set of verbal descriptions. There is a need to determine the predicted numerical values of parameters that could ensure the proper quality of the educational multimedia edition design. To obtain a specific quantitative quality indicator of the process under study, it is advisable to use methods and tools of fuzzy logic. The basic principles of fuzzy logic are identical to the logic of fuzzy sets, which is characterized by fuzzy, blurred boundaries.

It should be noted that the main tool of fuzzy logic is fuzzification [17, 18]. When it is impossible to represent the characteristics of technological processes in a numerical format, they should be replaced with a fuzzy description that accounts for the significance of their values within the overall set. The mathematical interpretation of membership functions enables the formation of term sets. Enhancing the model's adequacy through fuzzification serves as the foundation for modeling the predictive assessment of multimedia design quality. The inverse of this process is defuzzification [19, 20].

To obtain a high level of quality in the process of producing editions, it is necessary to ensure a meaningful, consistent and orderly implementation of production procedures. This approach contributes to the production of rational management decisions during the implementation of all stages and allows providing direct performers with a solid theoretical and applied base, which will serve as a kind of reference not only for the implementation of technical operations, but also for a creative component.

In view of the above, the purpose of the study is to develop a fuzzy system for predictive quality assessment of the educational multimedia editions based on the analysis of key factors and quality assessment by means of fuzzy logic. Thus, the main objectives of the study are: to develop a multilevel model of fuzzy logical inference for the formation of an integral quality indicator of educational multimedia editions; to construct membership functions of linguistic variables and calculate their values using fuzzy logic equations; to determine the integral quality indicators of the studied process by defuzzication of fuzzy sets according to the centre of gravity principle; to develop a fuzzy system for predictive quality assessment of multimedia editions.

The main contributions of the authors in this study:

– The authors have formed term-sets of linguistic variable values and developed a multilevel model of fuzzy logical inference for the formation of an integral quality indicator of the educational multimedia edition design.

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– The authors have performed fuzzification and defuzzification of the fuzzy set and developed a model for predictive quality assessment of the educational multimedia editions.

– The authors have developed a fuzzy system that allows determining the predicted quality indicator of the educational multimedia edition design based on the values of the input parameters.

2. Related Works

The results of the analysis of literary sources indicate the relevance of the problem of assessing the quality of educational multimedia editions. Many scientific publications are devoted to the influence of interactive multimedia e-books on the learning process, which emphasizes the significance of our study not only from a theoretical but also from a practical point of view.

In [21], the influence of multimedia books on the interest level of high school students in studying natural sciences was studied. The experimental group of students used interactive multimedia e-books, and the control group studied using printed textbooks. The results showed that students who used electronic books demonstrated significantly greater interest compared to those who studied using traditional textbooks. This indicates that the integration of multimedia elements into educational materials can increase students' intrinsic motivation and interest in the subject. The results of the study [22] also showed that the use of multimedia e-books had a significant impact on the learning process of medical students compared to classic printed editions. However, the duration of the experiments does not allow assessing the long-term impact of using multimedia books on academic achievement.

The work [23] is devoted to the development of a prototype of an electronic manual. The main stages of creating a multimedia edition were described. Methodological recommendations were presented on the selection of sources, the distribution of material by sections, the formation of the textbook structure, design, and optimal use of multimedia capabilities. It is noted that a multimedia manual provides quick feedback and flexibility for regular correction.

The work [24] is interesting from the point of view of substantiating the importance of multimedia editions. The authors conducted a meta-analysis of studies devoted to the influence of multimedia elements in the context of emotional design on students' learning outcomes. The main results confirmed that emotional design contributes to the improvement of cognitive perception and involvement. In addition, it has a positive effect on the emotional state, intrinsic motivation, and satisfaction with the educational process, reducing the subjective perception of the material complexity. An integrated approach to the generalization of previous studies is important, which allowed ensuring the statistical validity of the results obtained.

However, the aforementioned studies have not considered the impact of the quality of multimedia product design on students' achievement. Therefore, our study can solve the problem of assessing the quality of multimedia edition design and become a significant theoretical basis for further scientific explorations.

The paper [25] examines the features of creating multimedia stories as an effective tool for combining art and science. The authors involve participants in creating stories, working with them as partners, rather than as objects of research. The results emphasize the significant impact of creative practices on people. However, the small number of participants and workshops may limit the generalizability of the results. As in the study [24], it is difficult to understand to what extent the quality of the created stories influenced the responses of the respondents. There is also no formalized presentation of the results, which complicates the comparison with other works or empirical verification of the obtained data.

The study [26] is devoted to the integration of multimedia data into recommender systems. Modern methods of using different types of multimedia content – images, audio and video – are analysed to improve the accuracy and relevance of recommendations. The results indicate an improvement in the perception of text information due to the addition of multimedia elements. The authors emphasize the importance of understanding the features of forming high-quality multimedia

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editions to create more personalized and accurate recommendations, but do not provide recommendations for assessing their quality.

At the same time, the analysis of literary sources has shown the lack of research focused on the selection of multiple factors and a comprehensive quality assessment of the educational multimedia editions. Thus, the development of a fuzzy system for predictive quality assessment of educational multimedia editions based on methods and tools of fuzzy logic is an urgent scientific task. This fuzzy system will be useful for developers of multimedia editions and will have a significant impact on the provision of quality educational services.

3. Materials and Methods

For predictive quality assessment of educational multimedia editions, fuzzy logic methods are employed, originally formalized by Lotfi Zadeh as an extension of classical set theory. The fundamental principle of fuzzy logic is the concept of fuzzy sets, which represent objects and parameters through membership functions. These functions define the degree of membership of a particular element within a set. Another key feature of fuzzy logic is its capability for linguistic modeling, enabling the representation of natural language expressions through fuzzy sets. This approach facilitates the development of expert systems and control algorithms that effectively handle uncertainty in input data.

Let V be the set of significant values related to the given problem. To establish the correspondence between the set V and the fuzzy subset N with the membership function $\mu_N(v)$, the following approach is used:

$$N = \left\{ \left(\mu_N(v), v \right), v \in V \right\}, \quad (1)$$

where $\left(0 \le \mu_N(v) \le 1\right)$.

The membership function establishes the membership degree of each element of the fuzzy set to the universal set: $N \in V$.

The fuzzy set V is represented, taking into account the conditions of discreteness and finiteness of the base scale, divided into certain parts or intervals:

$$N = \left(\mu_N(v_1)/v_1, \mu_N(v_2)/v_2, ..., \mu_N(v_n)/v_n \right) = \sum_{i=1}^{n} \mu_N(v_i)/v_i \quad , \quad (2)$$

In a simplified record, the fuzzy set V has the form: $N = \sum_{i=1}^{n} \mu_i / v_i$.

At the same time, the symbol "/" in the expression (2) does not indicate the division operation, but only conditionally attaches the membership function $\mu_N(v_i)$ to the element v_i, and the sign $\sum$ conditionally denotes the set of pairs $\mu_N(v_i)$ and v_i.

Finally, membership functions serve as identifiers of input values of linguistic variables in a fuzzy format. The set of values of the input variable v corresponds to the membership function $\mu(v)$.

It should be noted that linguistic variables are variables whose values are represented by words or word combinations of a natural language, for example, “Edition format”, “Edition type”, “Edition volume”, etc. (provided that they have a linguistic, not numerical, value). The set of values of a linguistic variable constitutes its term-set, a random element of which is called a term. For example, the terms “small”, “medium”, “large” constitute the term-set of the linguistic variable “Edition format”.

The process of creating a design for a multimedia edition will be considered as the function Q, the arguments of which are the factors of this process:

$$Q = F\left(S_{1_m}, S_{2_m}, ..., S_{n_m} \right), \quad (3)$$

where n_m is a number of factors of the m-th process.

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According to the expression (3), the technological process is represented as a procedure with a set of input variables $S_i\ \left(i=\overline{1,n}\right)$ and one output — the variable Q:

$$\left|\underline{S_i},\overline{S_i}\right|,\ i=\overline{1,n};\quad \left|\underline{Q},\overline{Q}\right|. \tag{4}$$

The input set contains factors that are qualitative variables. Considering this, it is necessary to establish the set and the limits of the value assignment.

$$V=\left\{v^{(1)},v^{(2)},...,v^{(j)}\right\}, \tag{5}$$

where $v^{(k)},\ k=\overline{1,j}$ — conditional units with the weight coefficient j.

To determine the variable Q according to (4), the following expression is obtained:

$$Q=\left\{q^{(1)},q^{(2)},...,q^{(g)}\right\}. \tag{6}$$

Universal sets, represented by expressions (4)–(6) establish the domains of input and output linguistic variables and ensure the fulfilment of the dependency (3). In parallel, linguistic variables are assessed by means of a natural language, such as: “small”, “medium”, “large”, etc.

The process of constructing the membership function of linguistic variables of the educational multimedia edition design can be described in more detail.

For the formalized representation of the linguistic term Q, a universal fuzzy set $V=\{v_1,v_2,...,v_n\}$ is used with linguistic variables and ranks $r_Q(v_i)$ in the range $v_i(\mathrm{i}=1,...,\mathrm{n})$. Thus, the formalized representation of the linguistic term “quality of multimedia edition” Q, according to [16], has the form:

$$Q_F=\left\{\frac{\mu_Q(v_1)}{v_1},\frac{\mu_Q(v_2)}{v_2},...,\frac{\mu_Q(v_n)}{v_n}\right\}, \tag{7}$$

where $Q_F\subset V$; $\mu_Q(v_i)$ is a membership degree of the element $v_i\in V$ to the set Q_F.

A set of values $\mu_Q(v_i)$ are connected by logical operations $\wedge$ and $\vee$. This technique allows one to obtain a quantitative expression of the desired membership function of a linguistic term Q.

Then the distribution of membership degrees will be as follows:

$$\frac{\mu_1}{r_1}=\frac{\mu_2}{r_2}=...\frac{\mu_n}{r_n}, \tag{8}$$

where $\mu_i=\mu_Q(v_i)$; $r_i=r_Q(v_i)$ for all $i=1,...,n$.

This takes into account the condition: $\mu_1+\mu_2+...+\mu_n=1$.

To determine the ranks of factors, the numerical values of the membership functions are calculated from the relations:

$$\left.\begin{aligned}
&\mu_1=\left(1+\frac{r_2}{r_1}+\frac{r_3}{r_1}+...+\frac{r_n}{r_1}\right)^{-1};\\
&\mu_2=\left(\frac{r_1}{r_2}+1+\frac{r_3}{r_2}+...+\frac{r_n}{r_2}\right)^{-1};\\
&.....\\
&\mu_n=\left(\frac{r_1}{r_n}+\frac{r_2}{r_n}+\frac{r_3}{r_n}+...+1\right)^{-1}.
\end{aligned}\right\} \tag{9}$$

To ensure sufficient detail, the formed variables are divided into two ranges. Then, based on the relative estimates of the linguistic term ranks, a square inverse symmetric matrix $A=a_{ij}$ is formed, where $a_{ij}=r_i/r_j$ for $i,j=1,2,3$.

Thus, the following expression will be valid:

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$$\left.\begin{array}{l} Q_F = F\left(d_j, w_p, o_h\right) \to \max, \quad j = \overline{1.3};\ p = \overline{1.2};\ h = \overline{1.2}; \\ d_j > 0,\ w_p > 0,\ \ o_h > 0; \\ \mu_q\left(v_i\right) \to \max,\ v_i \in V,\ Q_F \subset V,\ i = \overline{1.3}. \end{array}\right\} \tag{10}$$

According to (10), it is necessary to achieve the maximum value of the function, which indicates the quality of the analysed technological process.

As a result of calculating the matrix, numerical values of the membership function are obtained for the specified ranks of linguistic terms at three points of division of the universal set. According to the established conditions, the matrix has the form:

$$W = \begin{bmatrix} 1 & \frac{r_2}{r_1} & \frac{r_3}{r_1} \\ \frac{r_1}{r_2} & 1 & \frac{r_3}{r_2} \\ \frac{r_1}{r_3} & \frac{r_2}{r_3} & 1 \end{bmatrix}. \tag{11}$$

With uncertain factor ranks, it is necessary to use a pairwise comparison matrix, the elements of which are obtained according to the scale of relative importance of objects according to Saaty [27], for each linguistic term.

The next stage is the formation of knowledge bases, knowledge matrices and fuzzy logic equations. The fuzzy knowledge base can be represented in the form of a knowledge matrix that connects input variables (factors of influence on the quality of multimedia editions) with the output variable (the result of the implementation of the technological process). To construct a knowledge matrix, a system of statements "if-and-then", "if-then-else", "if-or-then-else" is used. Based on the knowledge matrix, a system of fuzzy logic equations is formed, which allows obtaining numerical values of membership functions and an integral predictive quality indicator of educational multimedia editions.

The combinations of obtaining the result for two values of membership functions μ_1 and μ_2 have the form:

$$\mu_1 \vee \mu_2 = \max\left(\mu_1, \mu_2\right) = \begin{cases} \mu_1, if\ \mu_1 \geq \mu_2, \\ \mu_2, if\ \mu_1 < \mu_2, \end{cases} \tag{12}$$

$$\mu_1 \wedge \mu_2 = \min\left(\mu_1, \mu_2\right) = \begin{cases} \mu_1, if\ \mu_1 \leq \mu_2, \\ \mu_2, if\ \mu_1 > \mu_2, \end{cases} \tag{13}$$

where the operation $\vee$ in fuzzy logic equations indicates obtaining the maximum value, and the operation $\wedge$ indicates obtaining the minimum value.

A general representation of the fuzzy set Q is formulated:

$$Q = F_Q(D, W, O) = \left\{ \frac{\mu_{low}(Q)}{k_1}, \frac{\mu_{medium}(Q)}{k_2}, \frac{\mu_{high}(Q)}{k_3} \right\}, \tag{14}$$

where k_1, k_2, k_3 — numerical characteristics of Q.

The next stage of the study is the defuzzification of the set (14), which involves the normalization and evaluation of membership function values [14]:

$$Q = \frac{\sum_{i=1}^{m} \left[\underline{Q} + (i-1)\frac{\overline{Q} - \underline{Q}}{m-1} \right] \mu_i(Q)}{\sum_{i=1}^{m} \mu_i(Q)}, \tag{15}$$

where $\underline{Q}$ — low indicator; $\overline{Q}$ — high indicator; m — a defined number of terms.

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Summarizing the above, to develop a fuzzy system for predictive quality assessment of multimedia editions, it is necessary: to isolate the universal term-set of the analysed technological process and the corresponding terms; to synthesize a multi-level model of logical inference, which reflects the hierarchy of linguistic variables (factors) and their corresponding terms, and its highest-level component determines the output predicted quality indicator of educational multimedia editions; to determine the membership functions; to normalize the values of membership functions and compare them with the quanta of division of the universal set; to develop a fuzzy knowledge base and knowledge matrices using fuzzy logic statements of the type "if <condition>, then <conclusion (or action)>"; to construct fuzzy logic equations using knowledge matrices and membership functions that indicate the relationship between the membership functions of the input and output data; to construct an analytical expression for the formalized identification of the predicted result in the form of a fuzzy set obtained on the basis of a multilevel logical inference model and a fuzzy knowledge base; to carry out the process of defuzzification of the fuzzy set. It should be noted that during defuzzification of a fuzzy set, the values of the membership functions of linguistic variables with the domain of existence defined by the universal set are used [14, 16].

4. Results

Suppose the process of creating a design for a multimedia edition is a function $Q = F\left(S_1, S_2, S_3, S_4, S_5, S_6, S_7\right)$, the arguments of which are factors (linguistic variables) selected on the basis of expert evaluation. The value of this function is determined by the predicted edition integral quality indicator Q, expressed through partial indicators.

$$Q = F_Q\left(D, W, O\right), \tag{16}$$

where $D = F_D\left(d_1, d_2, d_3\right)$ — characteristics of the quality of the edition output data; $W = F_w\left(w_1, w_2\right)$ — the edition processing; $O = F_O\left(o_1, o_2\right)$ — the edition design.

The identified linguistic variables are presented in Table 1. Their notation, names, and values in conventional units are specified to standardize the values of linguistic terms. This allows for a high level of system adaptability to changes in requirements or analysis conditions.

Table 1. Term-sets of values of linguistic variables.

Variable	Linguistic essence of the variable	Universal set of values (the set V)	Linguistic terms (the set L)
d_1	Edition format	(1–3) c.u.	Small, medium, large
d_2	Edition type	(1–3) c.u.	Simple, complicated, complex
d_3	Edition volume	(1–3) c.u.	Small, medium, large
w_1	Page layout	(1–3) c.u.	Simple, complicated, complex
w_2	Proofreading	(1–3) c.u.	Simple, complicated, complex
o_1	Illustrative and multimedia design (volume of illustrations and multimedia)	(1–3) c.u.	Small, medium, large
o_2	Typographic design (font size)	(1–3) c.u.	Small, medium, large

A logical inference model is constructed that represents the hierarchical dependency of the quality of a multimedia edition on the values of the linguistic terms of the factors (Fig. 1).

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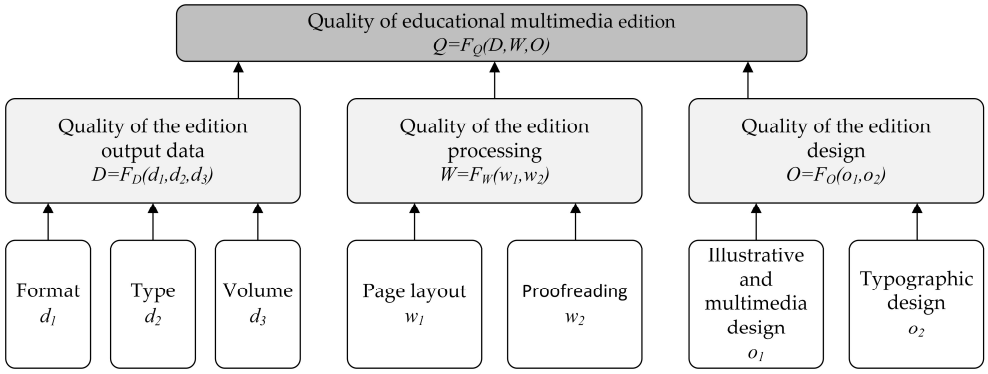

Figure 1: A model for forming a comprehensive quality indicator of educational multimedia editions.

The developed model contributes to the consistent establishment of predictive quality of the multimedia edition design by accumulating knowledge from the lowest to the highest of its levels.

Obtaining fuzzy sets is presented on the example of the factor "edition format". Calculations for other factors are carried out in a similar way. The matrix A is constructed for the linguistic variable "edition format". The universal set of values of the analysed linguistic variable is $V(d_1)=[1;2;3]$ c. u. The corresponding term-set of values is $L(d_1)=$<small, medium, large>.

Matrices for the terms "small", "medium" and "large":

$$A_{small}(d_1)=\begin{bmatrix} 1 & 4/9 & 1/9 \\ 9/4 & 1 & 1/4 \\ 9 & 4 & 1 \end{bmatrix} \quad A_{medium}(d_1)=\begin{bmatrix} 1 & 8 & 1 \\ 1/8 & 1 & 1/8 \\ 1 & 8 & 1 \end{bmatrix} \quad A_{large}(d_1)=\begin{bmatrix} 1 & 5 & 9 \\ 1/5 & 1 & 9/5 \\ 1/9 & 5/9 & 1 \end{bmatrix}$$

Calculated values of the membership functions:

$$\mu_{small}(v_1)=0.081;\ \mu_{small}(v_2)=0.183;\ \mu_{small}(v_3)=0.734.$$
$$\mu_{medium}(v_1)=0.47;\ \mu_{medium}(v_2)=0.058;\ \mu_{medium}(v_3)=0.47.$$
$$\mu_{large}(v_1)=0.762;\ \mu_{large}(v_2)=0.152;\ \mu_{large}(v_3)=0.084.$$

The next step is the classification of the values of the variable “edition format” according to expression $k_e=1/\max\mu_e(d_i),\ (i=1,2,3)$:

$$\mu_{small_n}(v_1)=0.11;\ \mu_{small_n}(v_2)=0.25;\ \mu_{small_n}(v_3)=1.$$
$$\mu_{medium_n}(v_1)=1;\ \mu_{medium_n}(v_1)=0.12;\ \mu_{medium_n}(v_1)=1.$$
$$\mu_{large_n}(v_1)=1;\ \mu_{large_n}(v_1)=0.2;\ \mu_{large_n}(v_1)=0.11.$$

According to formula (7), the following is obtained:

$$small\ format\ of\ the\ edition=\left\{\frac{0.11}{1};\frac{0.25}{2};\frac{1}{3}\right\}\ \text{c. u.;}$$
$$medium\ format\ of\ the\ edition=\left\{\frac{0.1}{1};\frac{0.12}{2};\frac{1}{3}\right\}\ \text{c. u.;}$$
$$large\ format\ of\ the\ edition=\left\{\frac{1}{1};\frac{0.2}{2};\frac{0.11}{3}\right\}\ \text{c. u.}$$

Based on expert judgments about the overall impact of the identified factors on the quality of the multimedia edition design development, a fuzzy knowledge base is formed, which, depending on the combinations of linguistic terms of the analysed linguistic variables, reproduces the algorithm for achieving the predicted quality.

According to the model for forming the comprehensive quality indicator (Fig. 1) and expression (16), the following is obtained:

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IF (D = low) AND (D = medium) AND (D = high)
AND (W = low) AND (W = medium) AND (W = high)
AND (O = low) AND (O = medium) AND (O = high),
THEN (Q = low) AND (Q = medium) AND (Q = high).

Based on the existing conditions, a knowledge matrix is constructed (Tab. 2):

Table 2. Representation of the linguistic variable Q.

Quality of the edition output data D	Quality of the edition processing W	Quality of the edition design O	Quality of the multimedia edition Q
low	medium	low	low
medium	low	low	low
medium	medium	low	medium
high	medium	medium	medium
high	high	high	high
high	medium	high	high

Fuzzy equations used to describe the procedure for forming the quality of multimedia edition design and the membership functions for the terms "low", "medium", "high":

$$\mu_{low}(Q) = \mu_{low}(D) \wedge \mu_{medium}(W) \wedge \mu_{low}(O) \vee \mu_{medium}(D) \wedge \mu_{low}(W) \wedge \mu_{low}(O)$$

$$\mu_{medium}(Q) = \mu_{medium}(D) \wedge \mu_{medium}(W) \wedge \mu_{low}(O) \vee \mu_{high}(D) \wedge \mu_{medium}(W) \wedge \mu_{medium}(O)$$

$$\mu_{high}(Q) = \mu_{high}(D) \wedge \mu_{high}(W) \wedge \mu_{high}(O) \vee \mu_{high}(D) \wedge \mu_{medium}(W) \wedge \mu_{high}(O)$$

Based on expert statements regarding the sets $L(d_1, d_2, d_3)$, $L(w_1, w_2)$, $L(o_1, o_2)$, logical statements are formed regarding lower-order linguistic variables: “quality of the edition output data”, “quality of the edition processing”, “quality of the edition design”.

IF (d_1) = (small, medium, large)
AND (d_2) = (simple, complicated, complex)
AND (d_3) = (small, medium, large),
THEN (D) = (low, medium, high).

IF (w_1) = (simple, complicated, complex)
AND (w_2) = (original layout, non-typesetting, typesetting),
THEN (W) = (low, medium, high).

IF (o_1) = (small, medium, large)
AND (o_2) = (small, medium, large),
THEN (O) = (low, medium, high).

Based on the above statements, corresponding knowledge matrices are constructed (Tab. 3–5).

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Table 3. Representation of the linguistic variable D.

Edition format d_1	Edition type d_2	Edition volume d_3	Quality of the edition output
medium	complex	large	low
small	complex	large	low
medium	complicated	large	medium
medium	complicated	medium	medium
large	simple	small	high
medium	complicated	small	high

Table 4. Representation of the linguistic variable W.

Layout w_1	Proofreading w_2	Quality of the edition processing W
complex	simple	low
complicated	simple	
complex	complicated	medium
complicated	complicated	
simple	complex	high
complicated	complex	

Table 5. Representation of the linguistic variable O.

Edition illustrative design (illustration volume) o_1	Edition typographic design (font size) o_2	Quality of the edition design O
large	small	low
large	large	
medium	small	medium
medium	large	
medium	medium	high
small	medium	

Fuzzy logic equations are formed for the terms of the knowledge matrices presented in Tables 3–5.

$$\mu_{low}(D)=\mu_{medium}(d_1)\wedge\mu_{complex}(d_2)\wedge\mu_{large}(d_3)\vee\mu_{small}(d_1)\wedge\mu_{complex}(d_2)\wedge\mu_{large}(d_3);$$
$$\mu_{medium}(D)=\mu_{medium}(d_1)\wedge\mu_{complicated}(d_2)\wedge\mu_{large}(d_3)\vee\mu_{medium}(d_1)\wedge\mu_{complicated}(d_2)\wedge\mu_{medium}(d_3);$$
$$\mu_{high}(D)=\mu_{large}(d_1)\wedge\mu_{simple}(d_2)\wedge\mu_{small}(d_3)\vee\mu_{medium}(d_1)\wedge\mu_{complicated}(d_2)\wedge\mu_{small}(d_3).$$
$$\mu_{low}(W)=\mu_{complex}(w_1)\wedge\mu_{simple}(w_2)\vee\mu_{complicated}(w_1)\wedge\mu_{simple}(w_2);$$
$$\mu_{medium}(W)=\mu_{complex}(w_1)\wedge\mu_{complicated}(w_2)\vee\mu_{complicated}(w_1)\wedge\mu_{complicated}(w_2);$$
$$\mu_{high}(W)=\mu_{simple}(w_1)\wedge\mu_{complex}(w_2)\vee\mu_{complicated}(w_1)\wedge\mu_{complex}(w_2).$$
$$\mu_{low}(O)=\mu_{large}(o_1)\wedge\mu_{small}(o_2)\vee\mu_{large}(o_1)\wedge\mu_{large}(o_2);$$
$$\mu_{medium}(O)=\mu_{medium}(o_1)\wedge\mu_{small}(o_2)\vee\mu_{medium}(o_1)\wedge\mu_{large}(o_2);$$
$$\mu_{high}(O)=\mu_{medium}(o_1)\wedge\mu_{medium}(o_2)\vee\mu_{small}(o_1)\wedge\mu_{medium}(o_2).$$

For the defuzzification of the fuzzy set, the membership function graphs are constructed (Fig. 2).

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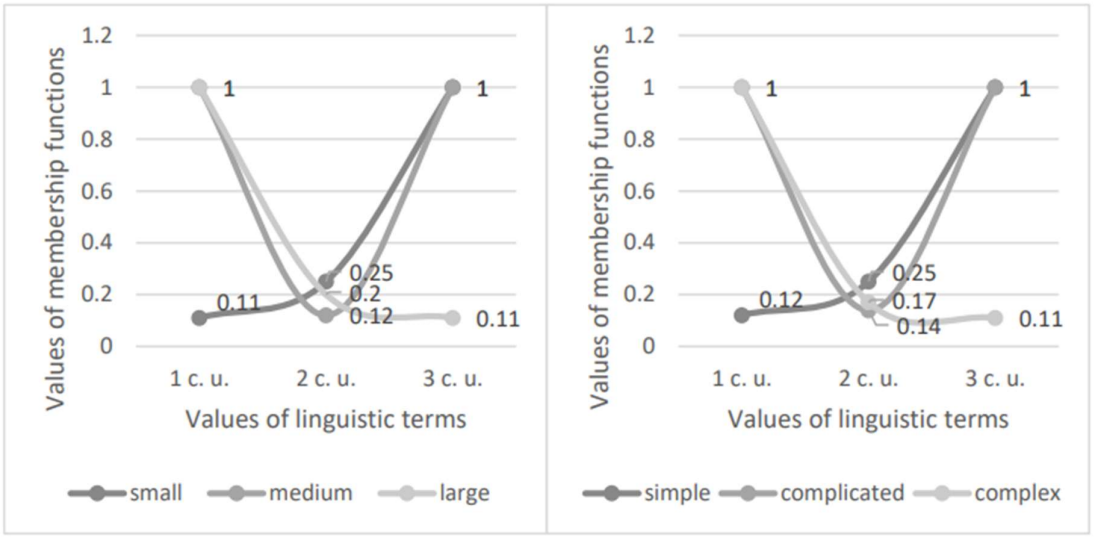
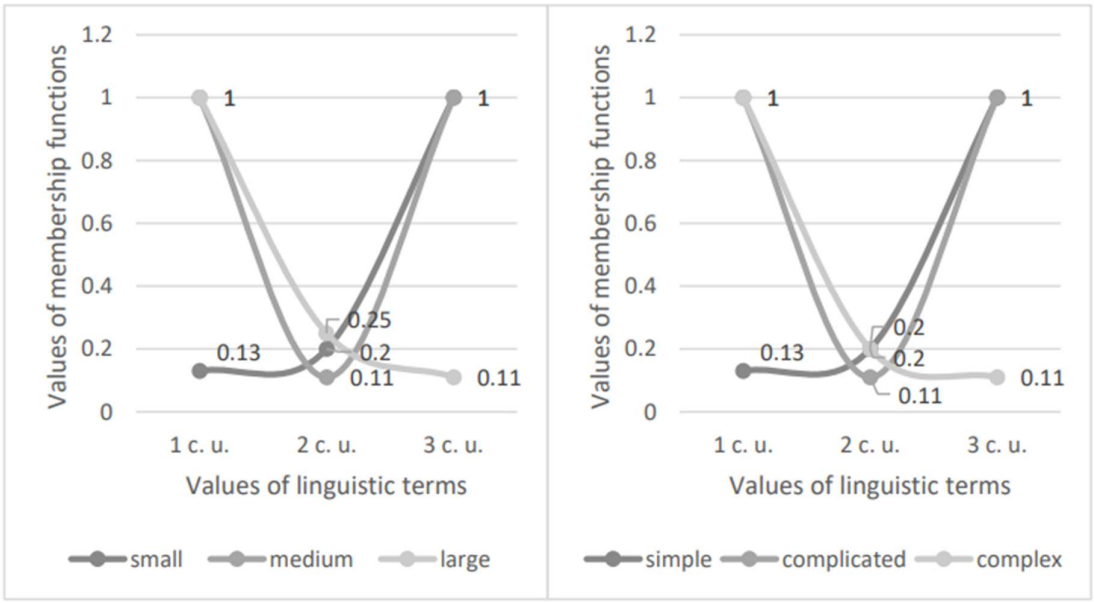


(a) (b)



(c) (d)

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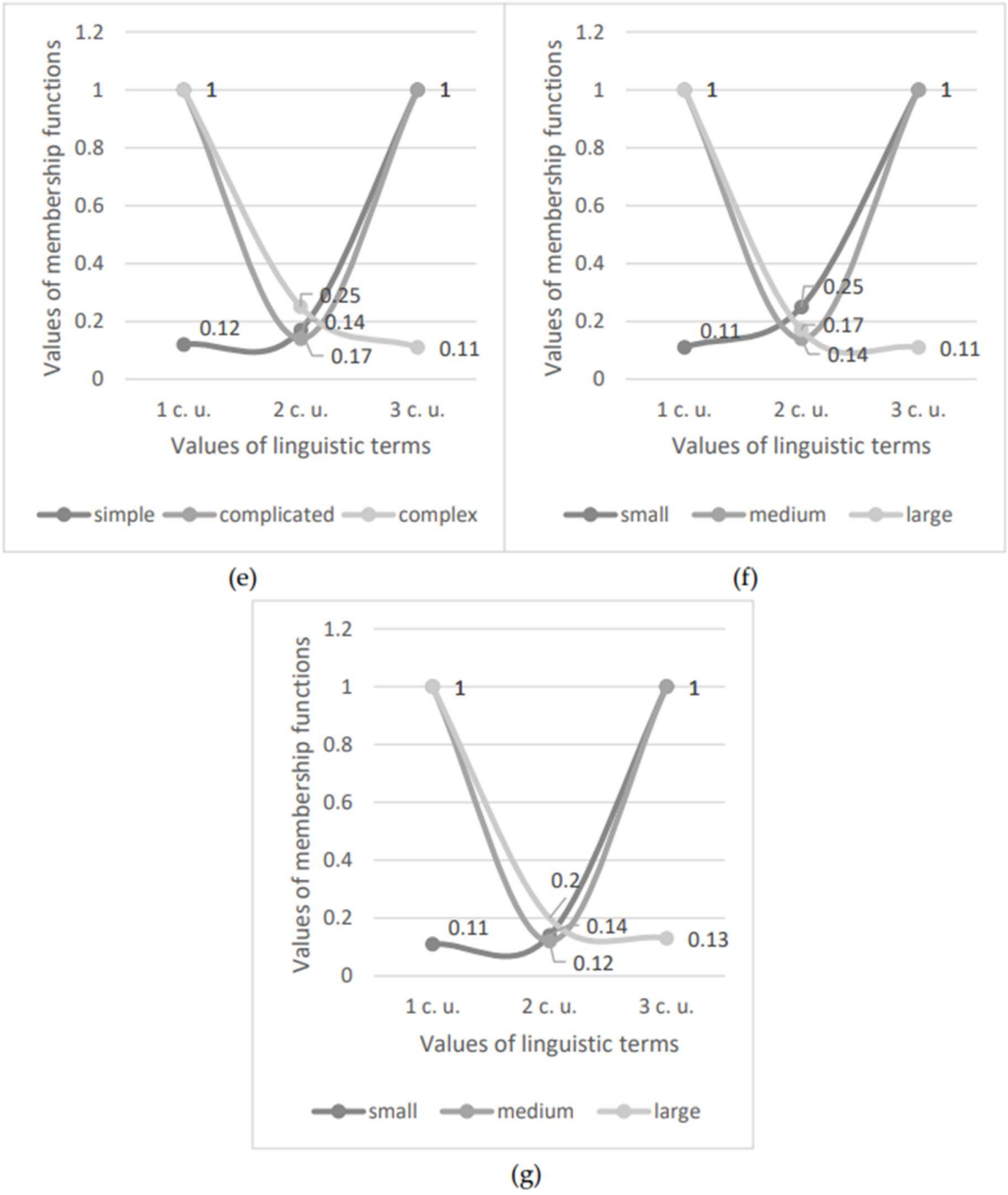

Figure 2: Membership functions of term-sets: (a) Edition format; (b) Edition type; (c) Edition volume; (d) Layout; (e) Proofreading; (f) Illustrative and multimedia design; (g) Typographic design.

The values of the terms are substituted into fuzzy logic equations and specific numerical values are obtained. For example, the indicators at the third division point of the universal set of values are taken and the following results are obtained:

$$\mu_{low}(D)=0.11;\ \mu_{medium}(D)=1;\ \mu_{high}(D)=1.$$
$$\mu_{low}(W)=1;\quad \mu_{medium}(W)=1;\quad \mu_{high}(W)=0.11.$$
$$\mu_{low}(O)=0.13;\quad \mu_{medium}(O)=1;\quad \mu_{high}(O)=1.$$

Obtained $\mu_{low}(Q)=0.13;\quad \mu_{medium}(Q)=1;\quad \mu_{high}(Q)=1.$

The quality of the multimedia publication is predicted based on the center of gravity principle (14). The calculation was performed according to expression (15). For the selected input parameters, $Q_{prognos.}$ = 70.48% is obtained at $m=3$ and interval values of 1%, 50%, 100%.

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Based on the conducted experiment, a model for predictive quality assessment of educational multimedia editions is constructed (Fig. 3), which contains two main stages: fuzzification, i.e., the transformation of a clear set into a fuzzy one, and the reverse process — defuzzification. According to this model, the software product "MEQuality" is developed to determine the integral quality indicator of educational multimedia editions based on the data entered by the user (Fig. 4). For the example, all maximum values are selected in conventional units.

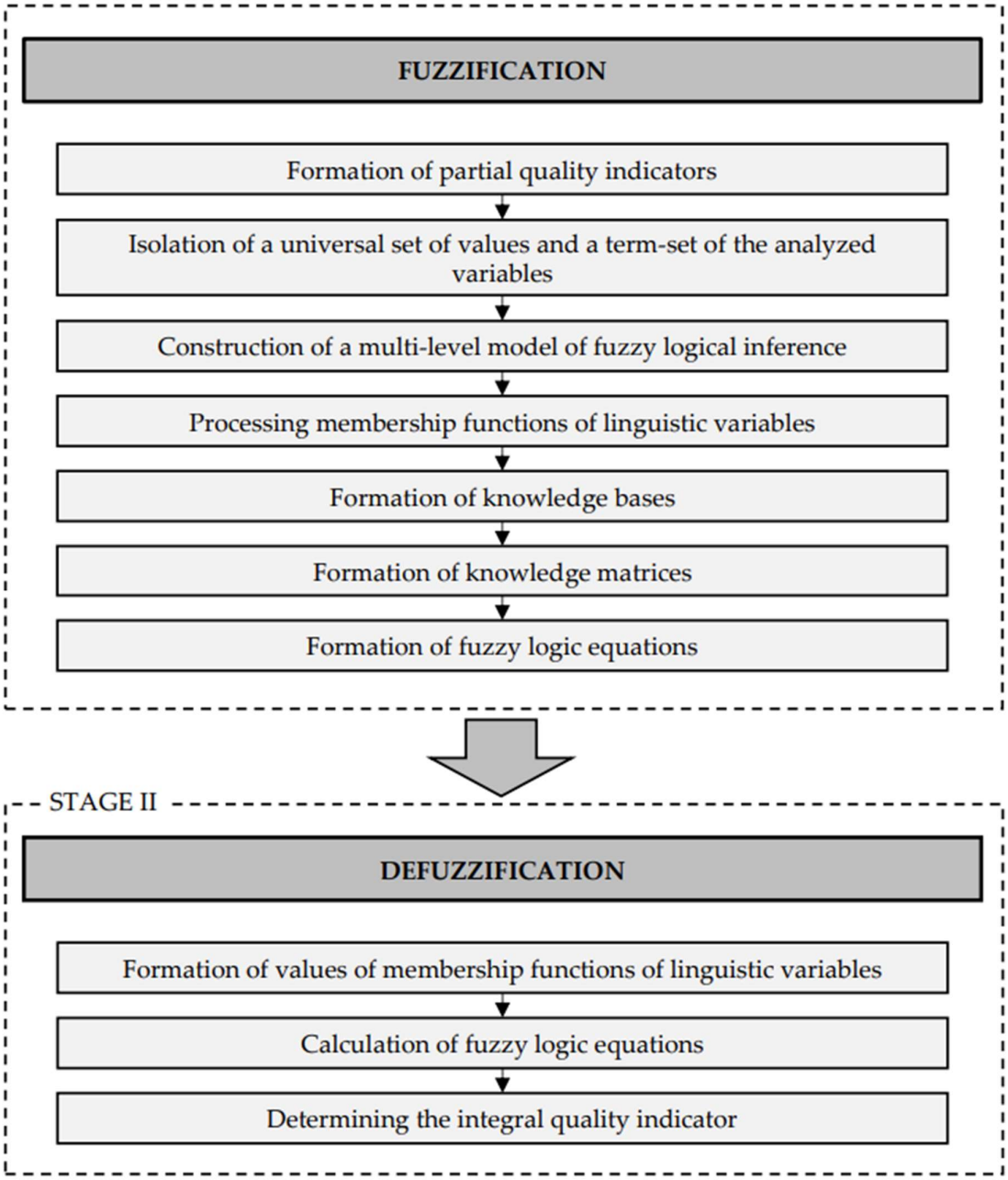

Figure 3: A model for predictive quality assessment of educational multimedia editions.

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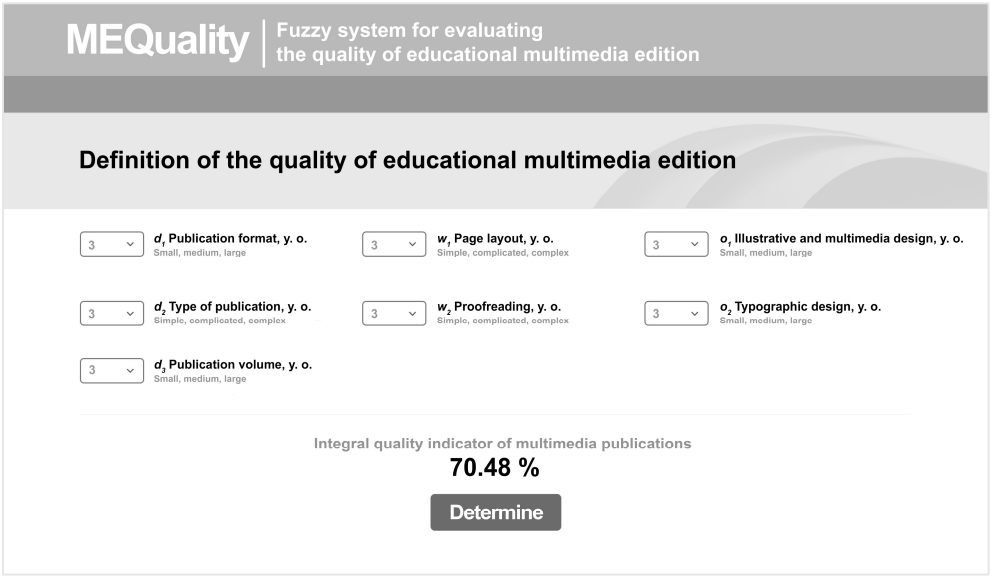

Figure 4: A fuzzy system for quality assessment of educational multimedia editions.

It should be noted that the quality of multimedia editions depends on many criteria, some of which are subjective in nature and have fuzzy characteristics. The complexity of formalization into clear mathematical models has led to the use of methods and tools of fuzzy logic. Fuzzy systems allow the implementation of expert knowledge in the form of "if-then" rules, which allows taking into account the subjective assessment inherent in the analysis of aesthetic, functional and ergonomic characteristics.

5. Discussion

Educational multimedia editions are an important tool of modern education, which contributes to increasing the efficiency of the educational process and developing skills for independent information processing. Multimedia data activates several channels of perception simultaneously, which significantly improves memorization and understanding of the material. In addition, the integration of theoretical knowledge with practical tasks meets the requirements of the modern educational environment, focused on a competency-based approach.

The developed fuzzy system for the quality assessment of educational multimedia editions allows one to determine the predicted quality indicator at the design stage for certain input parameters. In addition, there is the possibility of variable selection of values for adjusting the predicted indicator. A significant advantage is the specification of input parameters in conventional units, depending on the complexity of a certain operation or the data volume. For example, the user can independently determine how difficult the process of layout or proofreading a particular edition is for his team. Alternatively, how large the volume of illustrative or multimedia content is in terms of the number of specialists involved in its processing. This allows for a high level of system adaptability to changes in requirements or analysis conditions. Accordingly, during the design process, the team leader can make informed management decisions to obtain a product of proper quality.

For this purpose, a model of predictive quality assessment of educational multimedia editions is developed, which involves performing fuzzification and defuzzification. Fuzzification consists in replacing the concepts of a clear set with concepts of a fuzzy set. For this purpose, the process of creating a design of a multimedia edition is represented by a function, the arguments of which are linguistic variables selected on the basis of the expert evaluation. The predicted integral indicator is expressed through partial indicators that represent the essence of the quality of multimedia editions:

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the quality of the output data, the quality of the edition processing, the quality of the edition design. A detailed description of linguistic variables is carried out by isolating universal sets of values and the corresponding linguistic terms (Tab. 1). The results obtained are presented in a multi-level model of fuzzy logical inference (Fig. 1), which contributes to the consistent establishment of the predictive quality of the multimedia edition design by accumulating knowledge from the lowest to the highest of its levels. The values of the membership functions for each term of linguistic variables are determined and normalized relative to the unit, which make it possible to form fuzzy sets according to the formula (7). Fuzzy knowledge bases, knowledge matrices and fuzzy logic equations are formed for partial quality indicators, and for the highest level – "quality of multimedia edition". This becomes the basis for defuzzification – the reverse process of fuzzification. The values of the terms are substituted into fuzzy logic equations and an integral quality indicator of educational multimedia editions is determined according to the expression (15).

The main restrictions of the developed software product are that the user does not have the ability to add linguistic variables or change the value of the universal set. This is due to the complexity and clarity of the algorithm for determining the integral quality indicator. In addition, the sets of possible parameters are determined by experts in this subject area, which provides a theoretically sound result.

The results of the study can be used to support management decision-making regarding the selection of technological parameters and procedures for creating educational multimedia editions. This will contribute to increasing the overall efficiency of the educational process through the use of advanced educational resources, which will ensure the improved interaction between participants in the educational environment. The prospect of further research is associated with the integration of artificial intelligence for automatic updating of the knowledge base based on the analysis of new data and trends in multimedia editions and expanding the system through the introduction of additional (optional) criteria.

6. Conclusions

1. Based on the expert evaluation, partial indicators of the formation of the quality of educational multimedia editions are identified, and the corresponding linguistic variables are described. A model for the formation of a comprehensive quality indicator for educational multimedia publications is developed.

2. The values of the membership functions of linguistic variables are obtained by calculating the pairwise comparison matrices for each linguistic variable and its corresponding term-set of values. The terms of linguistic variables are represented by fuzzy sets.

3. Fuzzy knowledge bases are formed based on the expert judgments regarding the influence of the selected factors on the quality of the educational multimedia edition design, which reproduce the algorithm for achieving the predicted quality of the technological process under study. Fuzzy logic equations are constructed in accordance with the formed knowledge matrices.

4. A specific numerical value of the quality assessment of a multimedia edition is obtained by defuzzification of fuzzy sets according to the centre of gravity principle. The integral quality indicator for the selected input parameters is $Q_{prognos.} = 70.48\%$ at the maximum value 100%.

5. A fuzzy system for the quality assessment of educational multimedia editions is developed based on a model of predictive quality assessment and mathematical operations performed. This application is intended for predictive quality assessment of multimedia editions based on the values of input parameters selected by the user from the proposed sets. As a result of calculations, the system demonstrates a specific numerical value of the integral quality indicator, expressed in percentages. The developed software product will provide a theoretical and practical basis for informed decision-making in the context of performing technological operations aimed at creating the design of multimedia editions. This will contribute to a consistent and balanced determination of optimal parameters. Improving the quality of multimedia educational materials will contribute to increasing the efficiency of the educational process.

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