**UDC 004.89:004.42:004.4'272**

# INTERACTIVE INFORMATION SYSTEM OF FUZZY MODELING OF THE INTEGRAL EFFICIENCY OF THE USER INTERFACE

A. M. Syvak, R. I. Tatusko

*Lviv Polytechnic National University,*
*12 S. Bandera Street, Lviv, 79013, Ukraine*

*The article presents the results of developing an interactive information system for fuzzy modeling of the integral efficiency of a user interface, which integrates methods of fuzzy logic, adaptive visualization, and dynamic parameter adjustment. The proposed system enables the definition of weighting coefficients and membership functions for efficiency criteria — performance, cognitive load, usability, and adaptability of the interface. Based on these parameters, an integral efficiency indicator (E) is calculated and displayed in real time through graphical transformations. This approach allows researchers or developers to analyze the impact of individual factors on the overall evaluation, compare scenarios, and determine optimal ratios between criteria. The paper provides three simulation examples — technical, pedagogical, and user-focused — demonstrating the system's flexibility and its ability to model diverse priorities. The results confirm the effectiveness of fuzzy logic in accounting for subjective aspects of user experience that cannot be captured through traditional quantitative methods. The interactive implementation of the system enhances the convenience of the analytical process, ensures transparency of decision-making, and creates conditions for the development of next-generation intelligent user interfaces. The obtained results have practical significance for improving usability evaluation methods, optimizing educational and industrial environments, and designing adaptive, cognitively friendly interfaces capable of self-adjusting to user needs.*

***Keywords:*** *fuzzy logic, integral efficiency, user interface, interactive system, modeling, cognitive load, adaptability, usability, visualization, intelligent technologies.*

**Problem Statement.** Evaluating the efficiency of user interfaces (UI) in modern software systems is a complex multi-criteria task, as it involves both objective performance parameters and subjective indicators related to cognitive load, usability, and interface adaptability. Traditional analysis methods based on fixed numerical criteria or expert evaluations fail to account for the uncertainty inherent in human perception and user behavior. As a result, there is often poor consistency between quantitative metrics and the actual user experience.

This problem becomes especially relevant in the context of developing systems with pedagogical or technical focus, where achieving a balance between performance and cognitive comfort is crucial. In such cases, it is necessary to have a tool that allows dynamic adjustment of the weights of criteria and the level of their fuzzy memberships, as well as real-time visualization of how these changes affect the integral efficiency indicator.

The absence of interactive tools that combine fuzzy modeling, dynamic visualization, and real-time parameter adaptation complicates the decision-making process related to UI optimization. This creates the need for developing an interactive fuzzy modeling information system that would enable researchers and interface designers to experimentally determine optimal combinations of weighting coefficients and parameters, forming the basis for a scientifically grounded approach to evaluating the integral efficiency of user interfaces.

**Analysis of Recent Studies and Publications.** Experts note that fuzzy logic and fuzzy modeling have become among the most widespread methods for detecting errors and failures in complex information systems [1]. This approach aligns with the interdisciplinary trend of implementing innovative, adaptive, and user-oriented solutions [2]. Fuzzy logic enables the use of expert knowledge expressed through linguistic rules, allowing systems to process imprecise data and uncertainty, thereby bringing machine modeling closer to human reasoning [4]. Consequently, fuzzy logic serves as an ideal tool for managing inexact information under real-world conditions [4].

In the field of user interfaces (UI), traditional interaction systems are based on rigid binary logic and predefined scenarios that cannot fully capture the ambiguity of human behavior or the dynamic nature of user contexts [7]. Integrating fuzzy logic into interface design allows a system to interpret vague or ambiguous input data and respond in a more flexible and human-centered manner [7]. The use of fuzzy rules enables adaptive adjustment of the dialogue with the user, narrowing the gap between user intentions and system responses. Studies on intelligent user interfaces demonstrate that in uncertain and dynamic environments, the application of fuzzy logic and situational control is essential for ensuring real-time interface operation [3]. Multi-agent IUI architectures have been proposed, combining fuzzy inference, artificial intelligence methods, and knowledge bases to dynamically adapt interfaces to user actions and environmental changes [3]. Such fuzzy-logic-based intelligent interfaces significantly improve the flexibility and efficiency of human–machine interaction.

Adaptive visualizations and information dashboards also actively employ fuzzy modeling to support decision-making. In [5], an interactive interface for water quality monitoring based on fuzzy logic was presented, combining a standard water quality index with dynamic visualization tools (graphical indicators, membership diagrams, heat maps, etc.). The fuzzy model provided smoother and more nuanced interpretation of values near class boundaries compared to rigid threshold-based methods, reducing ambiguities by more than 15% at class limits [5]. This approach improved trend tracking and response time to water quality deterioration, confirming the effectiveness of fuzzy interfaces for operational monitoring and data visualization [5].

Fuzzy models are also actively applied for the integral evaluation of user interface efficiency by balancing multiple criteria. For instance, [6] proposed an intelligent decision-support system using fuzzy multi-criteria optimization to balance two key indicators of an advertising web interface — profitability (performance) and user comfort. The model accounts for uncertain parameters such as subjective intrusiveness of ads and temporal dynamics of their effectiveness [6]. The simulation results revealed that excessive visual intensity (bright animations, aggressive messages) beyond a certain threshold sharply increases user irritation while yielding only marginal engagement gains [6]. Conversely, moderate-impact strategies achieved a better compromise between user attention and comfort through fuzzy modeling [6]. This demonstrates that fuzzy logic methods can integrate diverse usability and efficiency criteria into a unified assessment, providing design recommendations for more balanced interfaces.

Another direction involves the creation of intelligent information systems with adaptive interfaces designed to simplify complex modeling tasks. Modern solutions introduce interactive interfaces that guide users through each modeling step and automatically execute time-consuming analytical operations [9]. In [9], an intelligent system for simulation modeling of information objects was described, featuring an adaptive interface and logic-linguistic models for automatic generation of analytical descriptions and procedural models. The system generates optimal solutions based on data structure analysis in a knowledge base and mathematical models for constructing fuzzy relations, significantly improving modeling accuracy and speed [9]. Automating model development and adaptation processes reduces user qualification requirements and training time, ensuring high modeling efficiency even for complex systems [9].

To support these approaches, new software platforms and tools focused on flexible and efficient fuzzy logic applications have emerged [8]. The FuzzyLogic.jl library [8], for example, provides an open toolkit for fuzzy inference designed for developer convenience and computational performance. It allows fuzzy systems to be described in a compact declarative form, supports standard inference mechanisms (such as Mamdani and Sugeno), and includes built-in visualization tools for interactive model tuning [8]. Modern implementations like FuzzyLogic.jl achieve high performance through code optimization and modern programming language capabilities, simplifying the integration of fuzzy models into real-world information systems [8]. Thus, the development of fuzzy modeling toolkits promotes the expansion of adaptive and intelligent user interfaces capable of effectively handling uncertainty and complexity in contemporary applications.

**The purpose of the article.** The purpose of the article is to develop and experimentally validate an interactive information system for fuzzy modeling of the integral efficiency of a user interface, which provides the ability to dynamically adjust the weighting coefficients and fuzzy membership parameters of evaluation criteria, as well as to visualize the impact of these changes on the aggregated efficiency indicator in order to support decision-making in the interface design process.

**Presentation of the Main Research Material.** The developed system is based on a fuzzy approach to evaluating the efficiency of a user interface using a set of criteria that combine quantitative and qualitative indicators. To achieve this, the concept of integral efficiency (E) was introduced, which is defined as the weighted sum of fuzzy memberships across individual criteria:

$$E = \sum_{i=1}^{n} w_i \cdot \mu_i(x),$$

$w_i$ – the weighting coefficient of the ( i )-th criterion, $\mu_i(x)$ – the membership function of the value ( x ) for the corresponding linguistic variable (for example, "high usability," "low cognitive load"), (n) – the total number of criteria.

The model allows complex, interdisciplinary interface properties (such as ergonomics, cognitive load, adaptability, etc.) to be represented as a fuzzy evaluation using triangular or trapezoidal membership functions.

The interactive information system (Fig. 1) is implemented as a web-oriented software product with the following main components:

Parameter Input Block: the user can define the values of criteria, their weights, and the parameters of membership functions through a convenient graphical interface.

Fuzzy Inference Module: performs the transformation of input values into fuzzy evaluations according to the defined membership functions.

Aggregation Module: calculates the integral efficiency according to the selected scheme (Mamdani, Sugeno, etc.).

Visualization Module: displays in real time the graphs of membership functions, the variation of the result (E) depending on input data, and the adaptation of weights.

The architecture ensures full interactivity: the user instantly observes the result of parameter changes, allowing sensitivity analysis of the influence of each criterion on the overall evaluation.

To demonstrate the functionality of the system, four main criteria for user interface evaluation were selected:

1. Simplicity of Use (Simplicity)
2. Cognitive Load
3. Adaptability
4. Task Completion Time

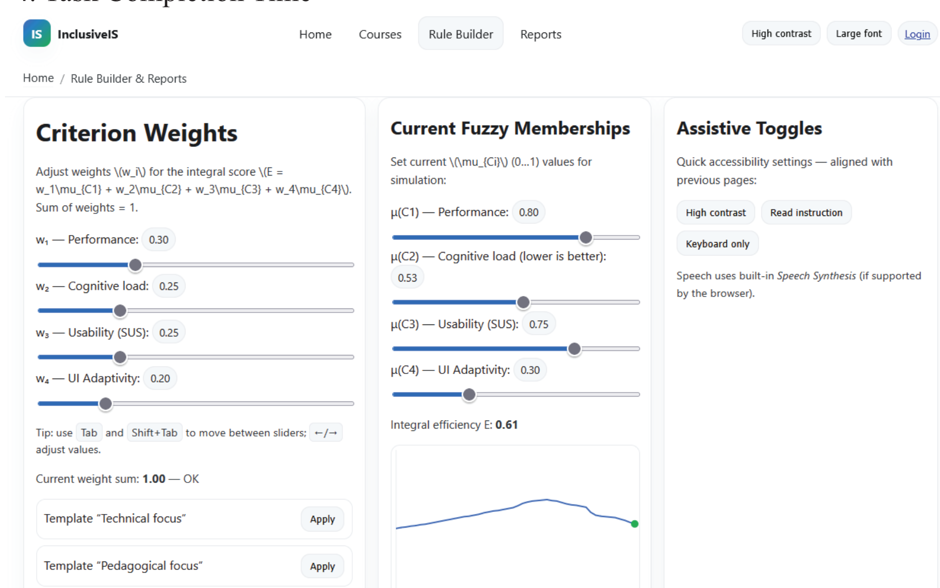


Fig. 1. Interactive Information System

Each criterion is represented as a fuzzy linguistic variable with terms (e.g., low, medium, high) described by triangular membership functions. The base ranges for each criterion were determined based on prior empirical studies.

The system implements a mechanism for dynamic adjustment of weighting coefficients ($w_i$), which enables modeling of various priority scenarios — for example, when adaptability is more important than speed, or vice versa.

An important feature of the system is the graphical visualization of all calculation stages. After changing the values of criteria or their weights, the user immediately sees:

Changes in membership functions and their current values;

Current results of fuzzy aggregation;

The integral efficiency indicator (for example, as a color scale or pie chart).

This enables rapid analysis of which indicators have the greatest influence on overall efficiency and allows the user to adjust parameters as needed.

Figure 2 shows a fragment of the interface of the implemented fuzzy modeling system, which consists of two functional panels — Criterion Weights and Current Fuzzy Memberships.

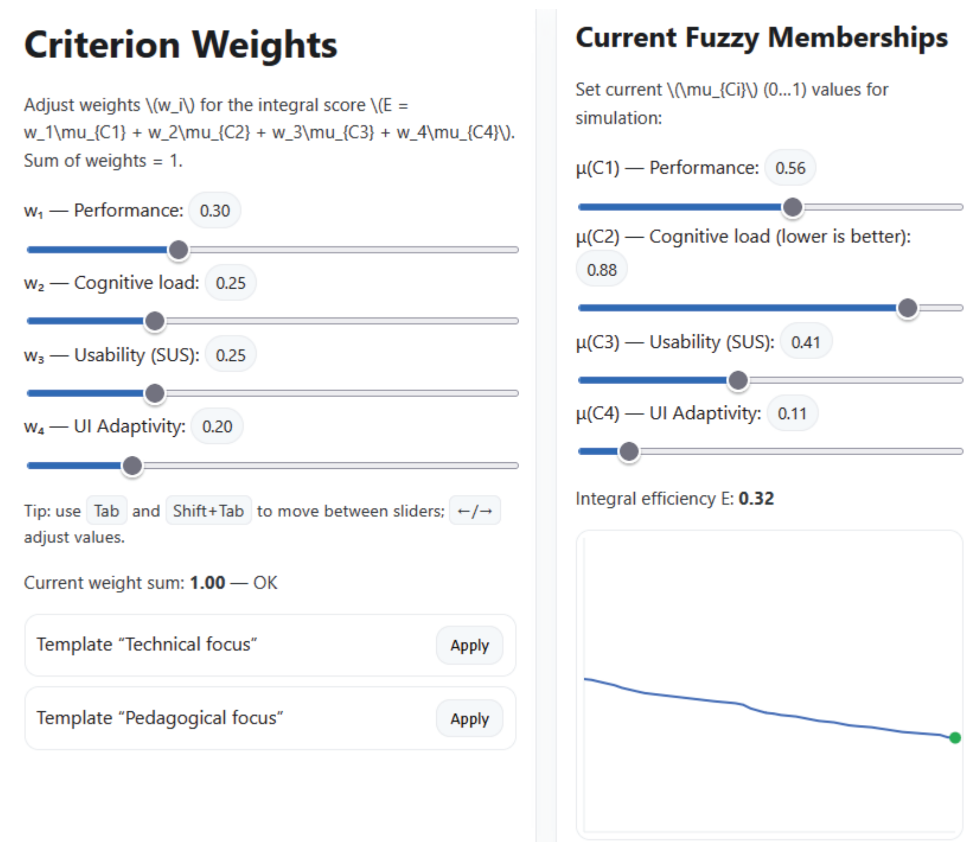


Fig. 2. Interface of the Fuzzy Modeling System with a Technical Focus

The user specifies the weight values for each of the four criteria included in the formula for integral efficiency. In the given example, the following weights are set: w1 = 0.30, w2 = 0.25, w3 = 0.25, w4 = 0.20.

The sum of weights equals 1.00, ensuring the correctness of the normalized computation of the integral indicator.

The value of each criterion is specified within the range from 0 to 1 as a result of evaluation or simulation. In the example: μ(C1) = 0.56, μ(C2) = 0.88, μ(C3) = 0.41, μ(C4) = 0.11.

The modeling result indicates a relatively low overall efficiency of the interface. Despite a high value of cognitive comfort μ(C2) = 0.88, the critically low level of adaptability μ(C4) = 0.11 and moderate values of the other criteria significantly reduce the integral score. This example demonstrates the sensitivity of the model to the combination of criteria and clearly illustrates the potential of the system for rapid identification of optimal parameter configurations in interface design.

The graph (Figure 3) illustrates the overall dynamics of efficiency variation — it can be observed that the total integral efficiency has a low value, indicating a critical need to improve performance and adaptability while maintaining the current level of cognitive load.

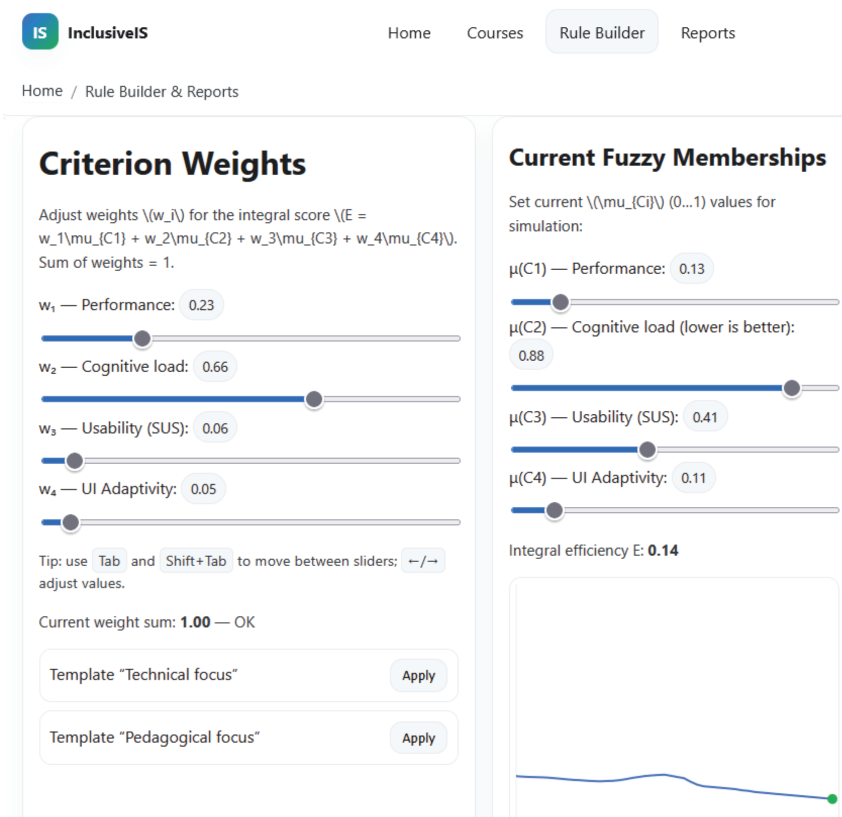


Fig. 3. Modeling Scenario with a Pedagogical Focus

This example demonstrates the capability of modeling scenarios with pedagogical prioritization, where the primary objective is to reduce the user's mental load. At the same time, it illustrates the importance of a balanced approach across all criteria — even high efficiency in one aspect cannot ensure overall success without adequate performance, adaptability, and usability.

The integral efficiency graph (Figure 4) shows a sharp increase at the final stage of the simulation — this outcome is primarily influenced by the criterion μ(C3). This confirms the significance of usability as a decisive factor in the overall evaluation when applying an appropriate weighting model.

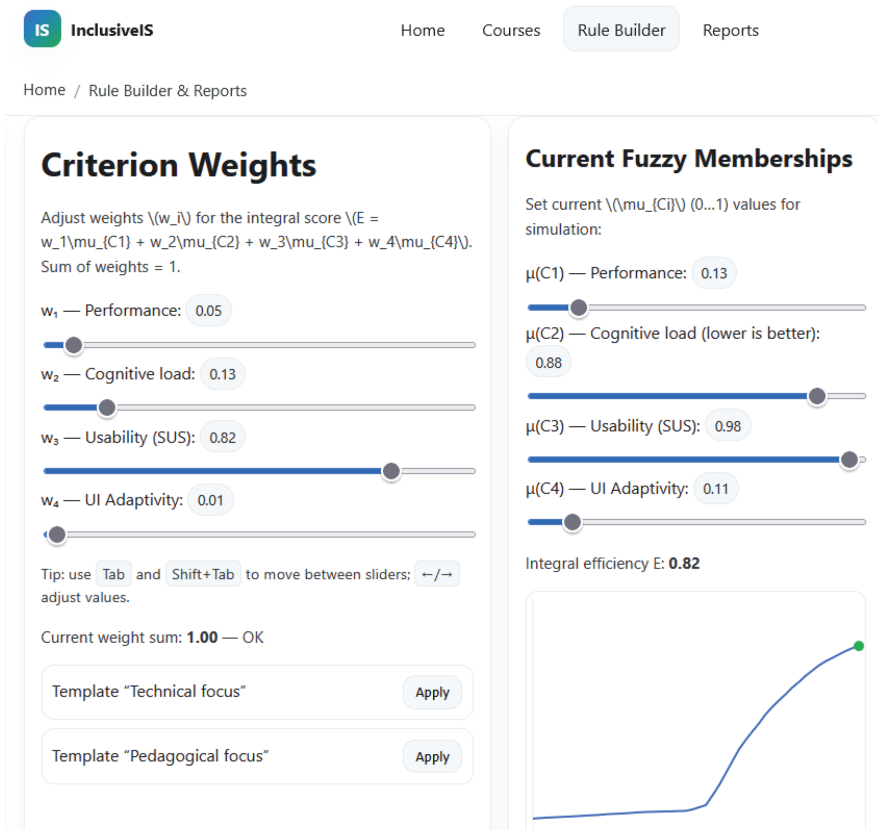


Fig. 4. Modeling Scenario with a Focus on Usability

Such a scenario is particularly relevant for adaptive systems designed for a wide range of users (including users with disabilities), where intuitiveness and interaction comfort are the top priorities.

Summarizing the results of the three conducted modeling scenarios (Figures 2–4), it can be concluded that the proposed interactive information system for fuzzy modeling of the integral efficiency of a user interface enables flexible analysis of the influence of weighting coefficients and fuzzy membership values on the aggregated efficiency indicator (E).

The shift in focus from technical to pedagogical and user-oriented modes demonstrates the sensitivity of the system to the priorities of individual criteria and confirms the adequacy of the mathematical model in reflecting real patterns of user–interface interaction. At the same time, the low (E) values observed in cases of criterion imbalance indicate the necessity of achieving an optimal balance between performance, cognitive load, usability, and adaptability.

Thus, the proposed system provides not only a quantitative evaluation of UI efficiency but also functions as an intelligent decision-support tool aimed at improving the quality, ergonomics, and inclusiveness of user interfaces..

**Conclusion.** As a result of the conducted research, an interactive information system for fuzzy modeling of the integral efficiency of a user interface was developed and tested. The system combines methods of fuzzy logic, adaptive visualization, and interactive parameter control. The proposed solution provides the ability to dynamically adjust the weighting coefficients and fuzzy membership values of the criteria, as well as to instantly visualize the impact of these changes on the integral efficiency indicator E.

The modeling confirmed that the developed approach enables a formalized evaluation of qualitative characteristics of user experience — performance, cognitive load, usability, and adaptability — by representing them as fuzzy sets and subsequently computing a generalized efficiency indicator. The interactive implementation enhances the flexibility and clarity of analysis, allowing users to modify model parameters in real time and observe how these adjustments affect system behavior.

The comparison of the three scenarios — technical, pedagogical, and user-centered (usability-focused) — demonstrated that the integral efficiency strongly depends on the distribution of weights among the criteria. The maximum values of E are achieved in balanced models, where no single criterion dominates excessively, confirming the importance of a harmonious combination of performance, cognitive comfort, usability, and adaptability in interface design.

The developed system can serve as an intelligent decision-support tool in software development, particularly in the fields of education, inclusive technologies, and adaptive digital environments. The results of the study demonstrate that the use of fuzzy logic makes it possible to account for subjective aspects of user experience that are difficult to formalize using traditional methods, while also increasing the accuracy of UI efficiency evaluation under ambiguous or multi-factor conditions.

Future research should focus on expanding the set of evaluation criteria, employing neuro-fuzzy algorithms for automatic tuning of weighting coefficients, and integrating the system with analytical modules for real-time user behavior tracking. The proposed approach forms a scientifically grounded foundation for creating inclusive, cognitively friendly, and adaptive user interfaces capable of enhancing the overall effectiveness of human–software interaction.

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**doi: 10.32403/0554-4866-2025-2-90-146-155**

# ІНТЕРАКТИВНА ІНФОРМАЦІЙНА СИСТЕМА НЕЧІТКОГО МОДЕЛЮВАННЯ ІНТЕГРАЛЬНОЇ ЕФЕКТИВНОСТІ КОРИСТУВАЦЬКОГО ІНТЕРФЕЙСУ

А. М. Сивак, Р. І. Татусько

*Національний університет «Львівська політехніка»,*
*вул. С. Бандери, 12, Львів, 79013, Україна*
*arsen.m.syvak@lpnu.ua, roman.i.tatusko@lpnu.ua*

*У статті представлено результати розроблення інтерактивної інформаційної системи нечіткого моделювання інтегральної ефективності користувацького інтерфейсу, що поєднує методи нечіткої логіки, адаптивної візуалізації та динамічного налаштування параметрів. Запропонована система забезпечує можливість задавати вагові коефіцієнти та функції належності для критеріїв ефективності — продуктивності, когнітивного навантаження, зручності та адаптивності інтерфейсу. На основі цих параметрів обчислюється інтегральний показник ефективності (E), який відображається у реальному часі у вигляді графічних змін. Такий підхід дозволяє досліднику або розробнику аналізувати вплив окремих чинників на загальну оцінку, проводити порівняння сценаріїв і визначати оптимальні співвідношення між критеріями. У роботі наведено три приклади симуляцій — технічний, педагогічний і користувацький фокуси, які демонструють гнучкість системи та здатність моделювати різні пріоритети. Результати підтвердили ефективність використання нечіткої логіки для врахування суб'єктивних факторів користувацького досвіду, що не піддаються традиційній кількісній оцінці. Інтерактивна реалізація системи підвищує зручність аналітичного процесу, забезпечує прозорість прийняття рішень і створює умови для побудови інтелектуальних користувацьких інтерфейсів нового покоління. Отримані результати мають практичне значення для удосконалення методів оцінювання юзабіліті, оптимізації навчальних і виробничих середовищ, а також розроблення адаптивних, когнітивно дружніх інтерфейсів, здатних до самопідлаштування під потреби користувача.*

***Ключові слова:*** *нечітка логіка, інтегральна ефективність, користувацький інтерфейс, інтерактивна система, моделювання, когнітивне навантаження, адаптивність, зручність користування, візуалізація, інтелектуальні технології.*

*Стаття надійшла до редакції 08.10.2025.*
*Received 08.10.2025.*