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SEMANTIC MODELS FOR WEB APPLICATION DESIGN

The development of web applications is often carried out within tight deadlines and under limited resources, which complicates adherence to the principles of high-quality design. The design of modern web applications requires consideration of a wide range of criteria that affect usability, accessibility, and the overall effectiveness of user interaction. Given the increasing complexity of digital interfaces, there is a growing need for the development of a theoretically grounded approach to evaluating design quality.

The aim of this study is to develop semantic models for formalizing the factors influencing the quality of web application design. The application of formalized models makes it possible to systematize expert knowledge, enhance the objectivity of decision-making, and ensure the reproducibility of results regardless of subjective factors.

This article identifies a set of factors that influence the quality of web application design. To achieve this, methods of expert evaluation and semantic modeling are employed. For the quantitative analysis of criterion significance, the rating scale method is applied, and indicators of variation and consistency of expert judgments are calculated. Three main categories of criteria are defined: ergonomics and cognitive principles of interaction; accessibility and inclusivity; and information architecture and visual design. Semantic models representing the relationships between factors within each category are constructed.

The proposed approach enables the formalization of expert knowledge and provides a foundation for the further automated evaluation of web application design quality using fuzzy logic methods. The developed semantic models can also be integrated into decision support systems for the design of digital products. Furthermore, they may serve as a basis for the development of educational materials and tools for auditing web application design in accordance with contemporary standards.

Keywords: web design, web application, factor, semantic network, expert evaluation.

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СЕМАНТИЧНІ МОДЕЛІ ПРОЄКТУВАННЯ ВЕБДОДАТКІВ

Розроблення вебдодатків часто відбувається у стислі терміни та з обмеженими ресурсами, що ускладнює дотримання принципів якісного дизайну. Проєктування сучасних вебдодатків потребує врахування великої кількості різноманітних критеріїв, що впливають на зручність, доступність та ефективність взаємодії з користувачем. З огляду на високу складність цифрових інтерфейсів зростає потреба в розробленні теоретично виваженого підходу до оцінювання якості дизайну. Метою дослідження є побудова семантичних моделей для формалізації факторів впливу на якість проєктування вебдодатків. Застосування формалізованих моделей дає змогу систематизувати експертні знання, підвищити об'єктивність рішень і забезпечити повторюваність результатів незалежно від суб'єктивних чинників.

У статті виокремлено множину факторів, що впливають на якість проєктування та дизайну вебдодатків. Для цього використано методи експертного оцінювання та семантичного моделювання. Для кількісного аналізу значущості критеріїв застосовано метод шкальних оцінок, а також розраховано показники варіації та узгодженості експертних суджень. Визначено три основні категорії критеріїв: ергономіка та когнітивні принципи взаємодії, доступність та інклюзивність, інформаційна архітектура і візуальний дизайн. Побудовано семантичні моделі зв'язків між факторами кожної категорії. Запропонований підхід дозволяє формалізувати знання фахівців та створити основу для подальшого автоматизованого оцінювання якості дизайну вебдодатків із застосуванням методів нечіткої логіки. Побудовані семантичні моделі також можуть бути інтегровані в системи підтримки прийняття рішень під час проєктування цифрових продуктів. Крім того, вони можуть слугувати основою для створення навчальних матеріалів, а також інструментів аудиту дизайну вебдодатків на відповідність сучасним стандартам.

Ключові слова: вебдизайн, вебдодаток, фактор, семантична мережа, експертне оцінювання.

Introduction

The key success criteria for any web application include an innovative approach, the ability to attract investment, flexibility in decision-making, effective team management, and a clear market entry strategy. According to [1], there are approximately 1.1 billion websites on the Internet; however, only 17% are actively maintained and regularly updated. This is due to the continuously increasing interest in web resources as drivers of overall progress. Nevertheless, because of high competition and rapid changes in the technological environment, a significant proportion of projects fails during the early stages of development [2, 3]. Despite these challenges, web applications have become fundamental tools in many spheres of human activity, including education, scientific research, medicine, social communication, and e-commerce.

The rapid advancement of technology, increasing competition, and growing user demands accelerate the development and digitalization of the educational process [4]. Educational web applications — comprehensive information products that integrate textual, graphical, audio, and video content into a unified structure — gain increasing popularity by providing interactivity and multimodal information delivery. In this context, websites can be viewed as an innovative form of traditional print media, adapted to modern technologies and the needs of the digital society [5, 6]. This contributes to the accessibility of educational platforms and the development of academic programs.

Websites have also become essential tools for the dissemination of scientific knowledge. Increasing demands for the public availability of research results and the need to justify science and innovation funding foster the growth of diverse digital practices. Academic and research-oriented web resources play a key role in knowledge dissemination, collaboration among scholars, and public engagement, indicating a transformation in scientific communication. Project-related scientific websites serve not only as informational platforms but also as tools for constructing scientific argumentation and promoting the values of contemporary science. At the same time, content analysis of web resources reveals only partial adaptation to the digital environment and limited use of its technical capabilities [7].

With the development of Web 3.0 technologies, the number of websites providing online healthcare services is increasing, contributing to a reduction in pressure on medical resources. Online medical services offer such advantages as 24/7 availability, elimination of geographical barriers, reduced financial costs, and faster access to medical care. However, to fully realize the potential of this technology, it is essential to establish user trust in online healthcare services [8]. Websites featuring physician ratings gain significant popularity, playing an important role in providing information that helps patients choose the appropriate healthcare provider [9].

The rise of social media influences corporate marketing strategies, altering the interaction between brands and consumers by giving the latter a more active role [10, 11]. However, studies indicate that consumer expectations may differ from the marketing strategies employed by companies. While clients seek quick and accessible communication, companies tend to focus on controlling information flows [10, 12]. Another important aspect is the role of social media in employment. Platforms such as LinkedIn serve as primary tools for recruitment, allowing employers to attract both active and passive candidates [10, 13].

According to [14, 15], website elements such as visual appeal, accessibility, and ease of use affect consumer characteristics, including normative evaluation, instant gratification, and impulsiveness. Other studies [16–18] confirm the positive influence of website quality on consumer behavior. For example, [16] highlights that usefulness, simplicity, and content interactivity encourage impulsive purchases. Thus, a well-designed website increases the likelihood of spontaneous buying behavior. In [17], it is emphasized that in order to strengthen customer engagement, internet marketers should improve the quality of web resources. Similarly, [18] confirms that well-developed web application elements significantly influence online sales.

It is worth noting that the initial impact on information perception and user engagement is determined by the quality of web application design. Specifically, interface ergonomics, intuitive navigation, and adaptability of web applications across different devices contribute to increased effectiveness of their use. Based on the aforementioned considerations, the importance of web application design quality across various sectors of public life can be concluded, highlighting the relevance of this research. The aim of the study is to develop semantic models of the factors that influence the quality of web application design. To achieve this goal, the following tasks must be addressed: conducting expert evaluation of generalized quality criteria, identifying a set of the most significant factors, and developing semantic networks of relationships between these factors.

Methods for the expert assessment of factors

The objective of the expert evaluation is to identify a set of criteria (factors) that influence the design and development of web applications from the proposed set of web application quality criteria. The application of this method is grounded in the competence of the selected specialists, their professional experience, and their ability to perform a well-reasoned analysis of the problem. The methodology of expert evaluation encompasses both the organizational aspects of expert involvement and the formal approaches to analyzing the obtained data. One of the most widely used methods of expert evaluation is the rating scale method [19]. Quantitative assessment of the relative significance of the factors is performed by assigning numerical values within a fixed scale, typically a 100-point scale. This system involves assigning each factor a value ranging from 0 to 100, where 0 indicates no influence, and 100 corresponds to the maximum level of significance. If multiple factors are deemed equally important, identical scores may be assigned.

To systematically represent the expert scores, a table is constructed (Table 1), which includes the number of experts, the number of evaluated criteria, and the scores assigned by each expert to each factor.

The total score for each factor is calculated using the following formula:

$$S_i = \sum_{j=1}^{m} X_{ij}, \qquad (1)$$

where X_{ij} is the score assigned to the *i*- th factor by the *j*-th expert, m is the total number of experts.

The arithmetic mean score of each factor is defined as follows: $\overline{X_i} = S_i / m$.

Table 1

Factor Weight Evaluation Matrix

Factors	Experts					
	1	2	3	…	j	…	m
G_1	X_{11}	X_{12}	X_{13}	…	X_{1j}	…	X_{1m}
G_2	X_{21}	X_{22}	X_{23}	…	X_{2j}	…	X_{2m}
G_3	X_{31}	X_{32}	X_{33}	…	X_{3j}	…	X_{3m}
…	…	…	…	…	…	…	…
i	X_{i1}	X_{i2}	X_{i3}	…	X_{ij}	…	X_{im}
…	…	…	…	…	…	…	…
G_n	X_{n1}	X_{n2}	X_{n3}	…	X_{nj}	…	X_{nm}

When a significant number of experts are involved in the evaluation process, differences in expert judgments inevitably arise. The key factor is the degree of these discrepancies, as it determines the level of consistency of the obtained results. The reliability of collective evaluation can only be ensured under the condition of a high level of agreement among expert judgments.

To assess the degree of variability and mutual consistency of expert opinions, quantitative indicators characterizing the statistical dispersion of values are used: range of variation L, standard deviation G, and coefficient of variation V. The application of these parameters makes it possible to objectively evaluate the level of consistency within group expertise and to determine its reliability. A high level of concordance in evaluations indicates the stability of the expert conclusion, while significant deviations may signal the need to clarify the evaluation criteria or involve additional experts to increase the accuracy of the analysis.

The range of variation L is calculated as the difference between the maximum and minimum scores assigned to a factor:

$$L = X_{\max} - X_{\min}, \tag{2}$$

where $X_{\max}$ is the maximum score assigned to the factor, and $X_{\min}$ — is the minimum score assigned to the factor.

The standard deviation K is obtained using the following expression:

$$K = \sqrt{\frac{\sum_{j=1}^{m}\left(X_{ij} - \overline{X}\right)^2}{m-1}}, \tag{3}$$

The coefficient of variation V is determined as follows:

$$V = \frac{K}{\overline{X}} \cdot 100\%. \tag{4}$$

The number of experts involved in the expert evaluation process depends on the complexity of the problem, the level of expertise of the specialists, the required reliability of the assessment, and the acceptable degree of divergence in expert opinions. The recommended number of experts can be determined using the following formula:

$$N = 0,5 \cdot \left(\frac{3}{b} + 5\right) \tag{5}$$

where b denotes the acceptable margin of error in the expert evaluation results, $0 < b < 1$.

To represent the relationships between web application design factors, the theory of semantic networks is applied. Semantic networks are among the most widely used forms of knowledge representation in artificial intelligence and natural language processing. They are based on the conceptualization of a subject domain through nodes (concepts) and edges (relationships between them). The idea of semantic networks was originally proposed as a method for modeling human associative memory. In their modern form, semantic networks are significantly modified and enhanced, and they play a key role in decision support systems.

The primary purpose of a semantic network is to represent real-world objects in the form of a graph, where each node corresponds to a concept, and the edges between nodes represent semantic relationships characterized by specific semantic meaning [20, 21].

Experiments

If the confidence level is set at 0.8, the margin of estimation error does not exceed 0.2. As a result of the calculation using formula (5), it is determined that the minimum acceptable number of experts in the group required to ensure the necessary accuracy of conclusions is 10 individuals.

Based on the results of expert evaluation, the set of factors influencing the quality of web application design includes several factors with significantly higher scores. Factors with substantially lower ratings are excluded. As an example, the results of expert evaluation for the five highest-rated factors are presented in Table 2.

Table 2

Fragment of the factor weight evaluation matrix

Factors	Experts										Total score, S_i	Mean score, $\bar{X}_i$	Range of variation, L	Standard deviation, K	Coefficient of variation, V
	1	2	3	4	5	6	7	8	9	10					
G_1	80	70	80	100	90	100	100	100	80	70	870	87	30	12,52	14,39%
G_2	80	80	70	90	80	90	100	90	90	70	840	84	30	9,66	11,50%
G_3	70	80	70	80	100	90	90	90	70	80	820	82	30	10,33	12,60%
G_4	90	70	60	80	70	80	80	80	70	60	740	74	30	9,66	13,06%
G_5	80	70	60	70	60	60	80	80	60	60	680	68	20	9,19	13,51%

As observed in Table 2, the measures of dispersion are minor, which indicates a low variability in expert assessments and an adequate level of consistency.

For the purposes of further research, the factors identified by experts as influencing the design and development of web applications are analyzed and classified into three main categories. Accordingly, the factor categories are defined as follows: E — ergonomics and cognitive principles of interaction; D — accessibility and inclusivity; I — information architecture and visual design. Criteria with similar functional purposes are generalized.

A set of factors influencing the design and development of web applications is obtained:

$$G = \{E; D; I\}, \tag{6}$$

with the following subordinate subsets: $E = \{E_1, E_2, E_3, E_4, E_5, E_6\}$ — the set of factors related to ergonomics and cognitive principles of interaction; $D = \{D_1, D_2, D_3, D_4, D_5\}$ — the set of factors related to accessibility and inclusivity; $D = \{I_1, I_2, I_3, I_4, I_5\}$ — the set of factors related to the quality of information architecture and visual design.

The distribution of factors influencing web application design across the three main categories is shown in Figure 1.

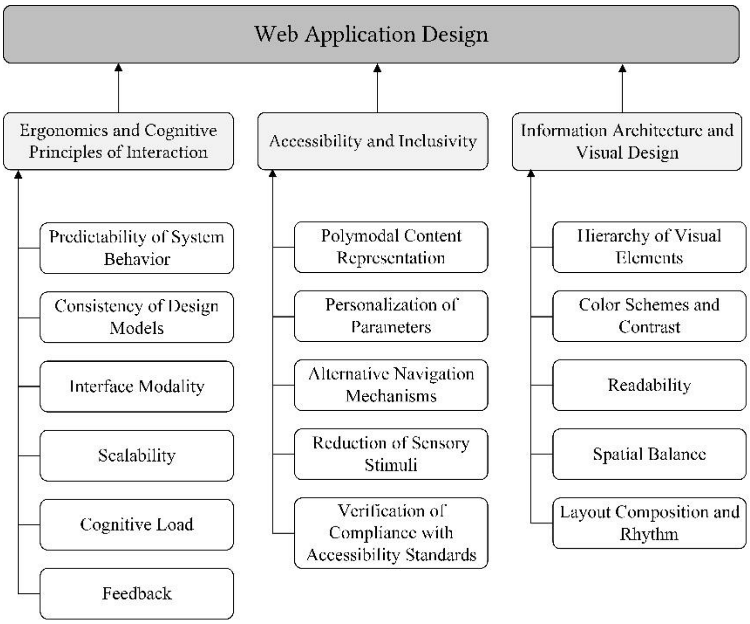

Fig. 1. Factors influencing the quality of web application design

The next stage of the study involves the development of semantic networks for the subordinate sets of factors influencing the quality of web application design (Figures 2–4). The primary purpose of a semantic network is to represent real-world objects in the form of a graph, where each node corresponds to a concept and the edges between nodes represent semantic relationships with defined semantic loads [20, 21].

The factors influencing ergonomics and cognitive principles of interface interaction determine the convenience, predictability, and effectiveness of user interaction with the interface: system behavior predictability (E_1) — the degree to which interface responses align with user expectations; consistency of design models (E_2) — the uniformity of stylistic and functional solutions across all system elements; interface modality (E_3) — controlled use of modal windows, dialogues, and state transitions; scalability (E_4) — the flexibility of design to efficiently adapt to changes in content and functionality; cognitive load (E_5) — the level of effort required to understand and use the interface; feedback (E_6) — informing the user about the outcomes of their actions through visual, auditory, and tactile signals.

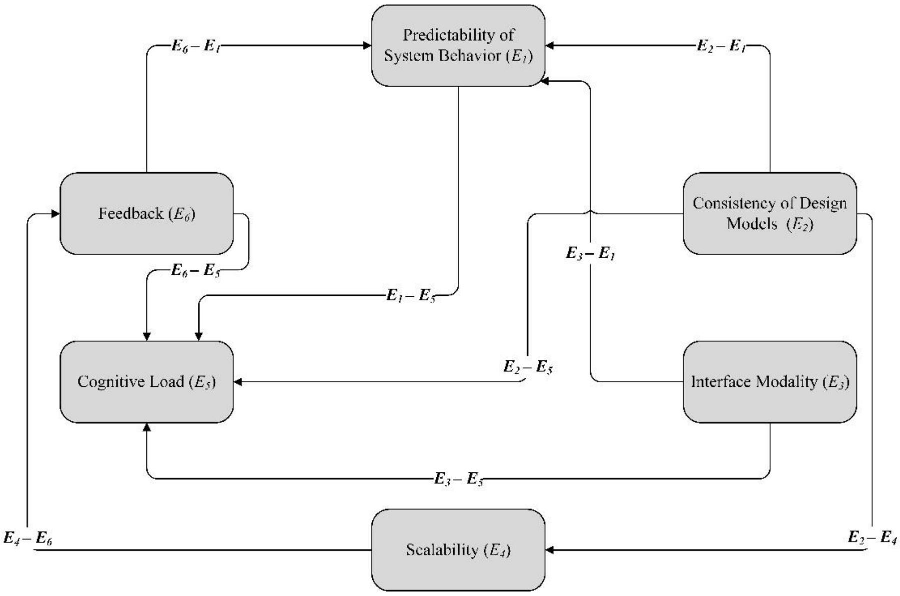

Fig. 2. Semantic model of relationships between the factors influencing ergonomics and cognitive principles of interaction with a web application interface

The set of factors influencing the accessibility and inclusivity of web applications includes those that ensure the adaptation of the interface for users with diverse abilities and needs: polymodal content representation (D_1) — duplication of information in various sensory formats (text, sound, haptic feedback, etc.); personalization of parameters (D_2) — the ability to adjust color schemes, font sizes, animation speed, and other display settings; alternative navigation mechanisms (D_3) — support for keyboard control, voice commands, and screen readers; reduction of sensory stimuli (D_4) — minimization of flickering, abrupt animations, and audio effects that may cause discomfort; verification of compliance with accessibility standards (D_5) — adherence to WCAG, ISO/IEC 29138-1:2018, and related standards.

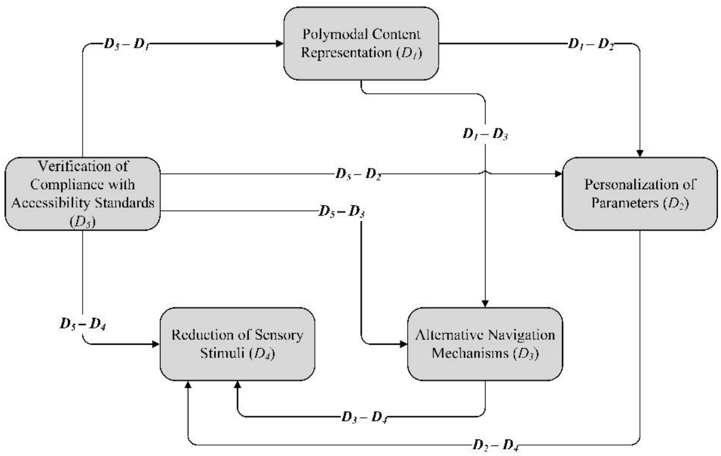

Fig. 3. Semantic model of relationships between factors influencing the accessibility and inclusivity of a web application

The set of factors influencing information architecture and content organization includes the following: hierarchy of visual elements (I_1) — the logical organization of interface components according to their significance; color schemes and contrast (I_2) — the alignment of the color palette with perceptual principles and accessibility standards; readability (I_3) — the selection of fonts, line spacing, and line length to ensure optimal text legibility; spatial balance (I_4) — the use of white space to distribute content harmoniously and reduce cognitive load; layout composition and rhythm (I_5) — the application of grids, modular systems, and proportional ratios to achieve a structured design.

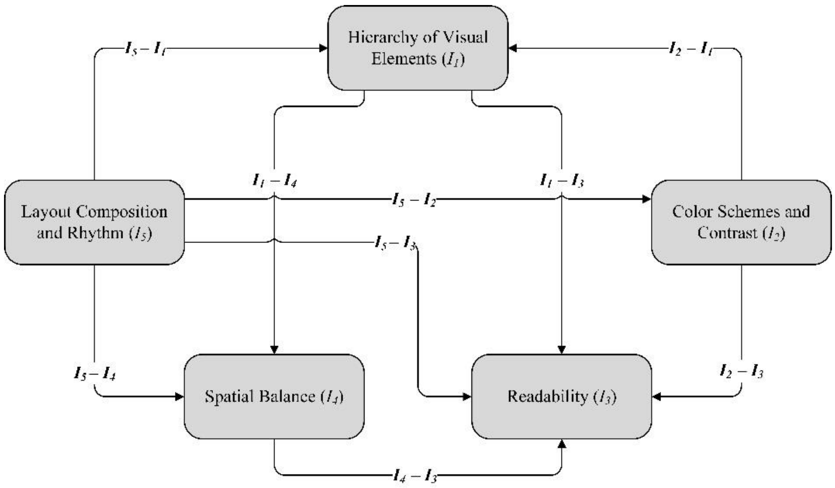

Fig. 4. Semantic model of relationships between factors influencing the information architecture and visual design of a web application

The developed semantic models serve as a basis for determining the prioritization of factors influencing the quality of web application design and for predictive quality assessment using fuzzy logic methods and tools.

Conclusions

An analysis of the factors influencing the quality of web application design is conducted. A set of relevant criteria is established to characterize aspects of ergonomics, accessibility, information architecture, and visual design. To determine the significance of each criterion, the rating scale method is applied. The expert data obtained are analyzed using statistical indicators, including variation measures and consistency coefficients of expert judgments. Based on the categorization of criteria, semantic models are constructed to represent the structural relationships among the factors. These models enable the formalization of knowledge in the field of web interface design and provide a foundation for their further integration into automated evaluation systems.

The conducted study has certain limitations. In particular, some of the criteria possess a subjective nature, which complicates their unambiguous formalization. The semantic models describe only the static structure of interrelationships and do not take into account the dynamic aspects of user interaction with the interface.

Future research should aim at expanding the base of expert assessments and refining the structure of the criteria. The application of fuzzy logic methods appears promising for addressing uncertainty in expert judgments. Another potential direction for development is the creation of a software tool to support the evaluation processes of web application design quality, based on the developed models.

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