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THEORETICAL FOUNDATIONS OF WEB SITE INTERFACE USABILITY ASSESSMENT

This paper presents how to redesign a website by applying a set of design principles to enhance the usability. The main objectives of the study are to find out the usability problems of the targeted interactive system in order to list out required suggestions to improve the website and to provide solutions by re-designing the existing interactive system. In order to implement the objectives of the project, we should initially evaluate the interactive system using usability evaluation. The outcome of the evaluation provides us information about the issues and requirements to design a new system. Based on the evaluation and its outcome, various methods will be used for resolving the problems while re-designing the website. This helps in identifying the problems which require usability improvements. The objective of this paper is to provide a conceptual framework and foundation for systematically investigating features in the Web environment that contribute to user satisfaction with a Web interface and uses motivation-hygiene theory to guide the identification of these features. Objects of research are generative systems with associative memory. Purpose is a development of a system for evaluating the hierarchy and heterogeneity of the interface of web pages using neural network technologies.

NEURAL NETWORK, MACHINE LEARNING, MEMORY, GENERATION, GENERATIVE MODELS, TEXT.

Козел О.Д., Колесников Д.О., Назаров О.С., Назарова Н.В. Теоретичні основи оцінки юзабіліті інтерфейсу веб-сайту. У цій статті представлено, як переробити веб-сайт, застосувавши набір принципів дизайну для покращення юзабіліті. Основними цілями дослідження є з'ясування проблем юзабіліті цільової інтерактивної системи для того, щоб сформулювати необхідні пропозиції щодо покращення веб-сайту та запропонувати рішення шляхом редизайну існуючої інтерактивної системи. Для того, щоб реалізувати цілі проекту, ми повинні спочатку оцінити інтерактивну систему за допомогою оцінки юзабіліті. Результати оцінки нададуть нам інформацію про проблеми та вимоги до проектування нової системи. На основі оцінки та її результатів будуть використані різні методи для вирішення проблем під час редизайну веб-сайту. Це допомагає виявити проблеми, які потребують покращення юзабіліті. Метою цієї статті є створення концептуальної основи для систематичного дослідження особливостей веб-середовища, які сприяють задоволеності користувачів веб-інтерфейсом, а також використання теорії мотивації та гігієни для визначення цих особливостей. Об'єктом дослідження є генеративні системи з асоціативною пам'яттю. Метою роботи є розробка системи оцінки ієрархічності та гетерогенності інтерфейсу веб-сторінок з використанням нейромережевих технологій.

НЕЙРОННА МЕРЕЖА, МАШИННЕ НАВЧАННЯ, ПАМ'ЯТЬ, ГЕНЕРАЦІЯ, ГЕНЕРАТИВНІ МОДЕЛІ, ТЕКСТ.

Introduction

The Internet has become a medium for a wide range of activities, including entertainment, communication, commerce, management, information sharing, and more. A website has become an integral part of any business, from retail to manufacturing. Social networks, personal business sites, web applications are prime examples that use web pages to display content. Over the past five years, the number of Internet users and the number of websites have increased significantly and are expected to continue to do so for a long time [1].

One of the most important criteria for successful business promotion on the Internet in terms of user experience has become customer acquisition and retention [2]. In the work related to the creation of an applied ontology for assessing the quality of user web interfaces, SEO was highlighted as one of the most important areas.

The author introduces the concept of element heterogeneity and describes its practical application [3].

From the business point of view, the user interface affects the quality of the provided services, creates a positive attitude towards the web service and leaves a desire to use it in the future. The quality of web interfaces is subject to increasing demands. User preference plays an important role [4]. Studies support this theory [5, 6, 7].

Technical aesthetics and ergonomics are applicable to the Web environment and are demanded by users. Research on the quality of user interface and its ergonomics is regularly conducted [6, 8-10], new theories are proposed, new tools are used to obtain reliable information.

The goal of the project is to develop a system for evaluating the hierarchicality and heterogeneity of web page interfaces using neural network technologies. To achieve this goal, it is necessary to solve the following tasks:

1) To study the subject area and conduct a comparative analysis of existing methods for evaluating hierarchicality and heterogeneity of the interface;

2) To develop a methodology for evaluating the hierarchicality and heterogeneity of the Web page interface;

3) design the architecture of a system for evaluating the hierarchy and heterogeneity of web pages using neural network technologies.

The project describes the theoretical justifications for creating a methodology for assessing quality based on the heterogeneity of elements and the creation of this methodology. It also describes the practical implementation of a quality assessment system based on current research in the field of UI/UX quality, using ISO standards, methods for assessing the heterogeneity of application components [8,11].

The system under development allows, based on the operation of a neural network, to determine the degree of compliance of the user interface with the established regulatory characteristics.

1. Subject area description

Today, evaluating the functional usability and visual appeal of a Web site is somewhat subjective and depends largely on human perception.

Due to differences in personal preferences and cultural backgrounds, different groups of website users can draw very different conclusions about the quality of the user interface. Therefore, it is difficult to perform an accurate and error-free usability evaluation using automated tools.

The implementation of the interface for working with an information system affects the success of that system: the user is interested in exploring the functionality, receives aesthetic pleasure, and feels comfortable if the implementation is based on general cultural principles and expectations. This affects both the duration of user interaction with the system and the level of user satisfaction after interaction with the system, and as a result, the desire to use the system in the future [6].

Since there are no other measures that provide a high level of reliability, user satisfaction is considered the most useful indicator of system success [10]. Satisfied users spend more time on a website and visit it more often. In general, user satisfaction can lead to audience retention and increased trust in the product. Therefore, it is important to improve the indicators that increase website satisfaction [3].

2. Modern methods for evaluating website usability

Modern usability assessment methods include a fairly wide range of methods and tools, ranging from user interviews and surveys to the use of sophisticated eye tracking devices and automated usability evaluation systems.

Modern usability evaluation methods can be divided into the following categories:

– Methods based on observation of user behavior,

– Methods based on self-evaluation of user behavior,

– Methods based on indirect user involvement [1,6].

In situations where users are directly involved, misinterpretation or incorrect answers to questions and low reliability can affect the reliability of the results. Expert methods, automated assessments, or process modeling not only take a long time to implement, but may also miss important issues and problems, reducing the reliability of the final assessment results.

Thus, based on the analysis of various usability assessment tools, it can be concluded that neither of the two existing assessment methods provides a complete, accurate and reliable usability assessment.

3. Analyzing Methods Used to Assess Interface Quality

Usability evaluation methods are divided into broad categories [4]:

1) Methods involving direct user participation:

– User observation — collecting information about the user's behavior and actions in the context of specific tasks while the user is working with the program.

– Critical event analysis — collecting data on specific events (positive or negative) that occurred during the user's work with the program.

– Performance measurements — collecting data on quantifiable performance characteristics to understand the impact of usability problems.

– Questionnaires — indirect evaluation methods that collect users' opinions about the user interface in specific questionnaires.

– Interviews — similar to questionnaires, but with more flexibility and personal contact with the person being interviewed.

– Participatory design and evaluation — methods that allow different types of participants to participate in the evaluation or design of systems.

– Thought aloud method — users continuously say out loud all their thoughts, beliefs, expectations, doubts, discoveries while using the system under test.

– Creative methods — methods that involve identifying properties of new products and systems, usually as a result of interactions among group members, often with users as members of such groups.

2) Methods that involve indirect user participation, which are used when it is not possible to collect usage data due to the absence of users, or in cases where they provide additional data and information:

– Model-based approaches — the use of models, which are an abstract representation of the product being

evaluated, that allow prediction of user actions.

– Document review methods — the study of existing documents by a usability specialist to provide a professional evaluation of the system.

– Automated evaluation — algorithms based on ergonomic knowledge that identify product defects by comparing them with specified data.

– Expert evaluation — an evaluation based on a usability specialist's knowledge, professionalism, and practical experience in the field of ergonomics.

Let's take a closer look at the automatic scoring methods:

1. Entropy of the RGB profile. The visual complexity of the system is estimated.

2. Information productivity. The ratio of the minimum amount of information needed to complete a task to the amount of information the user has to input.

3. Determination of the average time required by the user according to the GOMS, KLM methodology. Based on the averages, the average time spent by the user on the main tasks is calculated. User scenarios are determined individually for each project.

4. XML tree analysis. The complexity of the structure of the provided page is checked. This method requires specialization in web client development and principles of site optimization.

5. Number of classes into which interface objects can be divided.

4. Analyzing Methods Used to Assess Element Heterogeneity

The variety of web elements is one of the important criteria that make up the satisfaction score. This criterion affects the ease of assimilation of information, the perception of a web page and the ease of management of the system.

It is important to note that interfaces usually serve two main purposes [3]:

1. To provide information to the user.

2. Providing interaction with the system.

The process of creating interfaces is divided into two stages:

1. User Experience (UX) — shaping the interaction.

2. User interface (UI) — visualizes or materializes the interaction.

Experimental studies

The paper [4] presents tables describing such important attributes as understandability, well presented and organized information, interactivity, navigation (the ability to easily navigate between different pages of a resource), ease of use, which in varying proportions create a measure of heterogeneity. Their brief decoding is provided in this paper.

Learn more about the automatic scoring methods.

1. Understandability — the clarity and completeness of information on web pages.

2. Well-presented — the quality of information published on websites.

3. Ease of use — shows how easy it is for users to use the website's features.

4. Well organized — controlled (i.e. intuitive organization) and structured web environment.

These criteria were used to create a version of the questionnaire to assess the heterogeneity of the interface of neural network training sites based on user questionnaires. Based on these questionnaires, a neural network was constructed. The results and the weight of each parameter in the neural network are shown in Figures 1 and 2.

	System quality	Information quality	Security-privacy
Understandability	0.133	**0.854**	0.192
Reliability	0.266	**0.692**	0.253
Usefulness	0.216	**0.853**	0.137
Access	**0.807**	0.150	0.247
Friendliness	**0.828**	0.158	0.174
Navigation	**0.770**	0.282	0.065
Interactivity	**0.653**	0.201	0.480
Privacy	0.293	0.255	**0.795**
Security	0.156	0.206	**0.882**

Note: Bold values indicate the highest influence weight.

Fig. 1. Neural Network Weights for General Site Criteria

	System quality	Information quality	Security-privacy
Easy to comprehend	0.099	**0.809**	0.165
Well-presented	0.117	**0.773**	0.172
Accurate	0.263	**0.738**	0.169
Up-to-date	0.271	**0.667**	0.203
Relevant	0.141	**0.817**	0.134
Detailed	0.138	**0.796**	0.192
Speed of access	**0.729**	0.175	0.169
Availability	**0.778**	0.088	0.096
Ease of use	**0.801**	0.174	0.147
Well-organised	**0.794**	0.168	0.192
Page-loading	**0.702**	0.168	0.140
Hyperlinks	**0.749**	0.178	0.091
Two-way communication	**0.655**	0.192	0.425
Active control	**0.606**	0.109	0.456
Confidentiality	0.316	0.267	**0.701**
Authorisation	0.174	0.222	**0.800**
Integrity	0.225	0.218	**0.784**
Protection	0.130	0.185	**0.830**

Note: Bold values indicate the highest influence weight.

Fig. 2. Neural Network Weights for Private Site Criteria

As you can see, robustness is rated the highest by the neural network in the information quality section.

Similarly, well presented, well organized, and ease of use are highly rated by the trained neural network.

In another paper [3], similar metrics were obtained to create user interface quality evaluation systems. Figure 3 shows the ontology diagram.

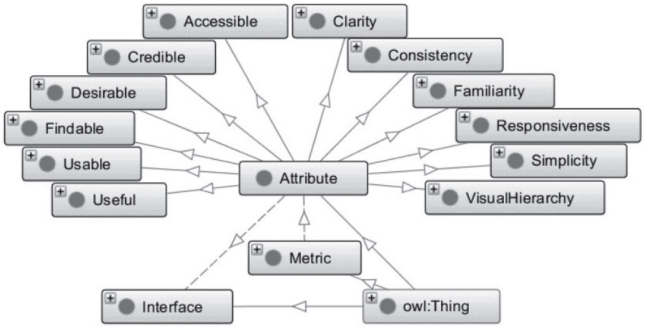

Fig. 3. User Interface Ontology Diagram

Based on the task, the directions of the ontology were determined to create a tool for evaluating attributes such as readability, comfort, cleanliness, and simplicity [3].

5. Standards and specifications

We managed to formalize these aspects using ISO standards related to human interaction with displays and interfaces. It is regulated by standards in the field of usability and human-machine interaction:

1. The User-Centered Interactive Systems Design Process provides guidance on how to organize the interface design process and integrate it seamlessly into the overall software production process. It describes the usability methods necessary for: determining the context of product use, identifying user and customer requirements for the system, prototyping and usability testing the product.

2. Ergonomics of human-computer interaction, description of the process of designing user-oriented interfaces. It describes in detail the maturity model of the organization in terms of the level of use of the UCD process. Recommendations for moving to higher maturity levels are given.

3. Ergonomics of multimedia user interface software. Recommendations are given for designing controls for multimedia products.

4. Human-system interaction ergonomics. Guidelines for access to human-machine interfaces.

5. Human-system interaction ergonomics. Usability-based methods for ensuring human-centered design.

Since ISO provide only technical requirements for the implementation of web pages, the visual and variable part of the design is outside the scope of the above standards. It is important to note that the standards define the color palette and normalize its contrast. This is an important criterion that can affect the heterogeneity of different elements together. They also standardize input/output methods, the basics of element behavior (for example, the principles of interaction with the "button" element), and their variability.

Expert research

Nielsen & Norman Group is a large expert firm that provides services for evaluating and improving UX/UI design.

Their publications have also been used to develop expert evaluation methods. In particular, an article that provides more than a hundred tips for creating a high-quality Web site [12]. Some recommendations related to the selected metrics were selected for the expert system.

Also, the works of NN Group employees describe patterns, best practices, and obvious mistakes in the design of web page elements [13-21].

Based on the knowledge gained, it is possible to develop the basis for a method to assess the heterogeneity of web page elements:

Summarizing the data from the different sources described above, we can assume that to assess heterogeneity, the following criteria should be taken into account: accessibility, quality of the information provided, ease of use, organization of components, comfort, cleanliness, simplicity.

The example of the implementation of an expert system using a neural network capable of assessing the quality of a web site shows that there is practical evidence for the quality metrics proposed. The resulting weights for the criteria give a good idea of the value of each evaluation criterion. Based on the given task, we can understand that there are all theoretical prerequisites for creating a system based on neural networks to assess the heterogeneity of elements.

The result of the research part is the developed concept of interface heterogeneity. Interface heterogeneity is the number of objects and their classes.

6. Analyzing and comparing analogues

In the course of studying analogs, we examined web applications for user interface evaluation that use screenshots as input data [12].

UsabilityHub is a web application that allows you to determine the quality of usability based on an uploaded screenshot. The analysis provides information on how easy it is for users to navigate a website page, identifies the elements that attract the most attention, and creates a heat map of clicks. The evaluation is based on a user survey.

UserPlus is a web application that allows you to determine the quality of usability based on an uploaded screenshot. Each screenshot is independently marked by the user of the service and then, after the survey, the result of the usability analysis is published for each marked interface element.

Usabilla is a web application that conducts user surveys based on uploaded screenshots and pre-prepared questions and generates analysis based on the results.

ConceptFeedback is an online resource where you can get a user interface evaluation from professional designers.

Based on the results of the comparative analysis, it can be concluded that most web applications use questionnaires and surveys of users and testers as a method of interface evaluation. A number of programs also monitor user activity on a web page. None of the existing analogues uses an automatic user interface evaluation system.

User interface evaluation according to the international standard is performed only in the UserPlus application. However, this evaluation method mainly refers to the individual elements of the interface rather than to the overall assessment of the interface usability.

Based on the results of the review of modern methods of evaluating web interfaces, as well as on the identified shortcomings among the studied analogues of web

applications for evaluating interfaces, there is a need to develop our own method of evaluating the hierarchical interface of web pages and web applications, which provides work with screenshots based on the developed method.

Characteristics of Analog Selection

There are currently no finished public products available to users, nor are there any implementations using the approach presented in this paper. Therefore, it was decided to study prototypes, the results of theoretical studies, and related solutions.

The research paper [4] describes theories such as the two-factor theory, the expectation of refutation theory, and the three-factor theory. These theories argue that the impact of a website attribute on satisfaction can have different weights for different characteristics, which means that their importance depends on their effectiveness. This fact leads to non-linear and asymmetric relationships that are difficult to evaluate using traditional methods. Therefore, successful results are obtained using neural networks, which are presented below.

The following analogues implement a part of the task at hand, so the description of each of them is a confirmed variant of the system component to be implemented, taking into account the specifics of the task at hand.

Evaluation of an expert system based on a questionnaire

Paper [3] attempts to determine the relationship between overall user satisfaction and website attributes. The paper uses the experimental results of a large questionnaire-based survey. The input data are also questionnaires. The purpose of the survey is to determine the overall satisfaction of website users by answering questions related to specific website attributes. The survey asked a set of 370 Internet users to rate the effectiveness of 18 specific and 9 general attributes, and to indicate their overall satisfaction on a nine-point scale ranging from "very dissatisfied" to "very satisfied". The results were tested and validated using reliability and validity procedures, showing that there is a relationship structure as certain general and specific website attributes create a link to user satisfaction. In this article, we try to find out the relationship between overall satisfaction and specific website attributes using neural networks to approximate the functions.

The result of the research is an expert neural network that shows the results of the value of each criterion on user satisfaction depending on the quality of that criterion. The results are shown in Figures 4-7.

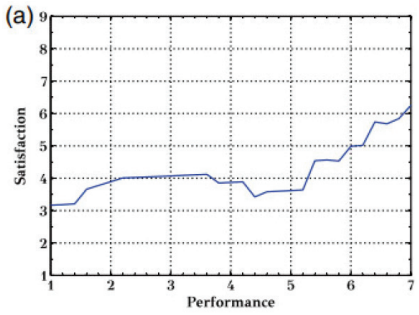

Fig. 4. Ratio of Performance to Satisfaction for the Understandability Metric

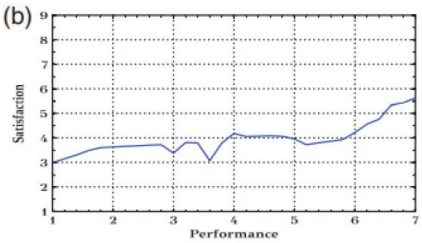

Fig. 5. Ratio of Performance to Satisfaction of the Well-Described Metric

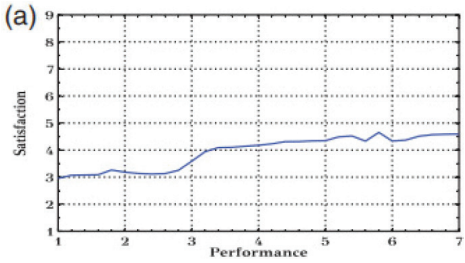

Fig. 6. Ratio of Productivity to Satisfaction of the Well-Organized Metric

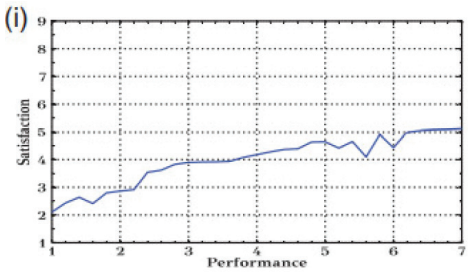

Fig. 7. Performance vs. Satisfaction Ratio for the Usability Metric

These figures allow us to understand the value of each of the criteria in the process of comparing them with their results.

It can be seen that these criteria together give an increase in satisfaction in relation to each other. It turns out that the proposed evaluation method should be productive for any image quality and the evaluation result should be intuitive for the system user.

Unfortunately, the system described in this paper requires an expert who is able to reliably convey the initial evaluation of a web page. In general, the neural network and its results are for research and exploratory purposes only and are not suitable for automated image processing.

Overview of the implementation of UI element retrieval using neural networks

Paper [22] provides comprehensive information on the performance of neural network models. The comparison includes Faster RCNN, Cascade RCNN, and YOLOV4 in Figure 8.

Run ID	Model	Overall precision	mAP@IoU 0.5	recall@IoU 0.5
67413	**baseline** Faster RCNN	0.94789	57.2	40.3
67833	Cascade RCNN	0.95035	68.16	53.3
67710	Cascade RCNN	0.94909	64.92	50.5
67722	Cascade RCNN	0.93463	72.33	58.5
67829	YOLOv4	0.93300	73.82	55.6
67707	YOLOv4	0.93125	79.24	59.4
67831	YOLOv4	0.92987	79.11	60
67972	Cascade RCNN	**0.95044**	71.53	55.6
67706	YOLOv4	0.93437	**79.36**	**59.8**

Run 67972: 10000 iterations; Run 67706: 7000 iterations

Fig. 8. Neural Network Performance Results

As you can see, YOLOv4 shows a good performance result. It should be clarified that when choosing the implementation tools and the technical experiment, it was decided to use YOLOv5s, since it returns the answer faster, which is extremely important for server applications.

We used 2950 images to train the neural network to search for UI elements: 2363 images were used to train the neural network, and 587 images were used for testing.

The knowledge gained from the analysis of related programs allowed us to choose the means of implementation, the future architecture of the system, the amount of necessary expert, training, verification and test data.

Selection of the means of realization

The choice of implementation tools is based on the knowledge of neural networks gained during training, as well as on the results of project and course work.

We chose the YOLOv5 neural network model to classify web page elements because it is quite compact and efficient and meets the performance requirements of server applications. Accordingly, the framework for running the neural network is PyTorch, the programming language is Python, and the framework is FastApi. Since some components of the system were developed during the internship and coursework, the second neural network, which plays the role of an expert, is implemented using the Keras framework, which was proposed for work during the training. Heterogeneity is one of the criteria for the quality of the user interface, so it was decided not to use frameworks to create SPA applications, as it is obvious that at this stage of client development it is unnecessary.

For the same reason, the search for tools and technologies for databases is not taken into account due to the small functionality of the program — the user simply has no reason to save images for further work.

The user is given the opportunity to download the current result, which is quite enough.

Technical Experiment

Two frameworks were chosen to implement the server API: Flask and FastApi. Both frameworks are positioned as easy to understand and easy to use.

To select the optimal framework, a technical experiment was performed: a prototype program was implemented using Flask and FastApi, and standard prediction models for YOLOv5s and YOLOv3 were used as a neural network to classify objects. As a result, the FastApi framework was chosen because of its implementation of asynchrony, the ability to easily create parallel threads, and simple and flexible tools for configuring server endpoints, such as simple and transparent validation implementation.

YOLOv5 was chosen as a preliminary model because it is a more productive version and requires less memory to run. An important factor was the speed of training, since the only place to train a neural network is provided by Google Colab, which has technical limitations in terms of resources and time. You can see the difference in the required resources in Figures 9, 10.

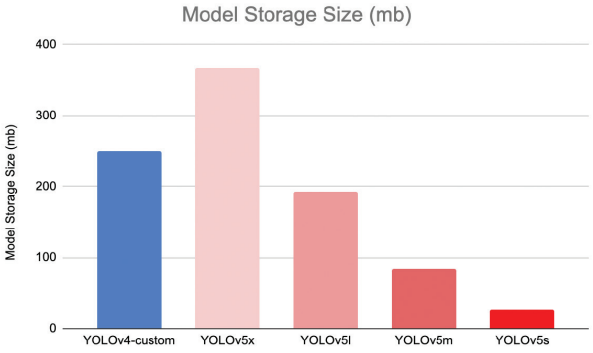

Fig. 9. Megabyte Model File Size Chart

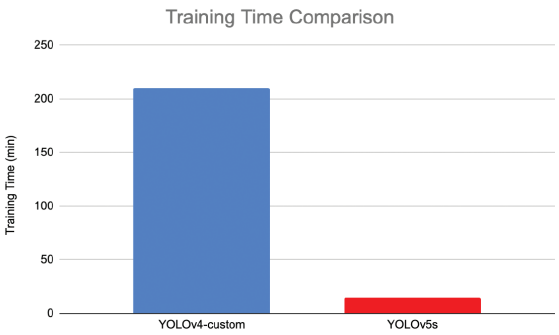

Fig. 10. Diagram of Neural Network Training Speed in Minutes

The choice of a simplified model had a positive effect on the quality of the trained model: more epochs improved the classification accuracy. As part of the task, it is first necessary to find all the classes represented in the image.

The accuracy of YOLOv5s is lower than that of YOLOv3, so it was decided to allow the user to choose a model if speed is not so important. The choice of YOLOv5s is also due to the fact that the latency is acceptable for mass processing, e.g. object classification of 850 Full HD images (1920 x 1080 pixels) in multi-threaded, asynchronous mode takes no more than two minutes using AMD FX-6300 CPU 6 6 threads instead of 4-5 minutes using YOLOv3 and full CPU utilization. See the System

Performance Testing section for more information. At the time of selecting system development tools, the current information is sufficient.

Conclusions

The quality of the user interface is a difficult concept to evaluate. The variety of web elements is one of the important criteria that make up the satisfaction score.

This criterion affects the ease of assimilation of information, the perception of a web page and the ease of managing the system. The relevance of the topic is confirmed by many works.

As part of this work, we have developed a web application for evaluating the hierarchical nature of web page interfaces based on the analysis of screenshots.

In particular, the following tasks were solved:

1) A review of existing methods for evaluating user interface usability and existing analogs.

2) Analyzed the requirements, developed a method for evaluating the hierarchy of web interfaces, and designed the architecture of the web application.

3) The subject area is studied and a comparative analysis of methods for evaluating interface heterogeneity is made.

4) Developed a methodology for assessing the heterogeneity of web page interface.

5) Designed the architecture of the system for assessing the heterogeneity of web pages using neural network technologies.

Further research is planned to solve the following tasks:

1) Extend the list of features of the hierarchy evaluation.

2) Investigate the relationship between expert opinion and the value of the metric to be calculated.

3) Combining the modules for hierarchicality and heterogeneity evaluation of the web page interface into a single system.

In addition to practical and research experience, the work provided invaluable experience in integrating trained neural network models and a client-server program.

The tasks of neural network integration and practical application were completed.

The work itself has further development potential: extending the evaluation methods, improving the current solution, publishing the service and providing access to it.

Conflict of Interest

The authors declare no conflict of interest.

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