N. Kulbaka, A. Pysarenko, O. Bondarenko

SOFTWARE FOR VIRTUAL TOURS

Abstract: The article discusses the methods and means of implementing a dialogue system using modern technologies of natural language processing, which will allow visitors to virtual art exhibitions to receive information about the exhibition, author and works in the form of an interactive conversation, which is built on the rules educational function in the "Exhibition" system, which modern web services of virtual exhibitions do not support.

The architectures of dialog systems, text classifiers, corpora of Ukrainian texts, means of implementation of dialog systems for web applications in JavaScript and Python are analyzed. Based on their capabilities, disadvantages and advantages, the tools for developing a virtual guide were chosen. The existing systems of artificial intelligence for excursions, namely the works of "Promobot" and "Pepper", are considered, as well as the existing dialogue systems "Siri" and "Alice". The necessity of creating the module "Guide" in the system "Exhibition" is revealed and substantiated. The architecture of the dialog system for conducting virtual tours in cooperation with the web service of art exhibitions has been designed.

The result is a dialogue system "Exi", which was integrated into a web service for organizing and conducting art exhibitions "Xolst". It has been experimentally proven that a virtual guide implements the necessary functionality for conducting tours, increases user interest in the exhibition, improves the perception of artwork and creates a positive emotional environment..

Keywords: dialog system; dialog manager; natural language processing; virtual tour; artistic work; graphs of knowledge; text corpus; JavaScript; Python.

Problem statement

Artificial intelligence is currently one of the most important areas in the field of information technology. Companies are trying to integrate decision-making systems, bots, voice capabilities, image processing into their products, because users have already got used to a fast and smart system. With the spread of three-dimensional graphics and VR-technologies, virtual reality has become popular [1], which cannot be said about art exhibitions, which despite their important role in aesthetic education, broadening horizons of ideological and material components, development of universal values, have lost their popularity and attract less and less people now.

In recent years, virtual tours have proven to be a promising area. Real exhibitions are turned into a virtual format using panoramic maps, in the foreign market there are platforms for creating and conducting virtual art tours by means of three-dimensional graphics online [2].

The problem is that virtual tours exclude the communication, and with it the informational function of exhibitions, which in the real world are performed by guides. Information to the works, if provided, then the usual textual description, which does not improve perception, which destroys the important task of the exhibition - the formation of the ability to analyze and develop the imagination [3].

It is possible to solve this problem by means of artificial intelligence in the field of natural language processing, but dialogue systems remain one of the most difficult tasks of computer science [4]. Their simplest implementations, chatbots, only partially fulfill their function. Full-fledged systems that process and generate natural language and perform tasks at the request of the user are few. The problem is increased by the scarcity of corpora of Ukrainian texts and data sets [5].

Therefore, it is desirable to implement the educational function in virtual tours, namely to introduce into the system "Exhibition" module "Guide" - a dialogue system-assistant, which will perform the function of forming a tour, means of attention, detail and problem statement; information function, answering questions about the exhibition and art theory; communication function, maintaining a conversation with the visitor. This will increase the audience of virtual tours.

Analysis of recent research and publications

The article [6] explores virtual spaces for the dissemination of cultural heritage, the study includes virtual experiments that were conducted by combining digital photogrammetry and computer 3D modeling. Two immersion instances are available for visualization and interaction with virtual environments: screen, keyboard and mouse (Desktop VR) and HTC Vive (VR visualization headset). We can see that the organization does not provide any organization of the tour itself. In a study [7], the authors test the hypothesis and assess the level of virtual walks around monuments and museum centers in Poland. The study used an evaluation model consisting of eight sub-indices, namely content, interactivity, support for people with disabilities, navigation, functionality, graphics, accessibility, additional features. From the results of the study, we observe that no tour provides user support with a guide, we also determine the same in the study [8].

The topic of applied digital gamification of museums is the closest to the implementation of a virtual guide. Thus, in the study [9] the authors give examples of software for question-answer games using chatbots. The authors note that because the principles of gamification are consistent with those that form the basis of human learning, which is based on play in childhood, it greatly helps to increase the cultural skills of visitors, with which I agree. The North Sea Oceanarium application, which simultaneously places visitors in the director's place, exploring exhibitions and encouraging them to create and publish their own content with augmented reality technology, is mentioned by the author in the article [10]. These applications also can not be considered the implementation of the tour, but they are a promising means of attracting attention and increasing the audience.

Summing up the research in the implementation of virtual tours, it is necessary to take into account the publication [11], in which the authors analyzed 100 mobile applications that were related to museum business, and noted that visitors can expect museum programs to offer basic information and support their navigation in the museum, but they should not expect that a typical application will have a lot of multimedia, gamified elements or augmented reality.

The use of AI technologies, in particular chatbots, in museums is considered in [12]. The authors provide a virtual museum guide "MAX", "Object Phone", which provides information on the exhibits, a chatbot, which allows users to follow different paths in the story of Anne Frank with brief information and links to additional content. From the research we understand that the software for organizing a dialogue with the visitor is based on the components of artificial intelligence, due to deep learning, focusing on identifying the intention (what information needs to be provided) and personalization of the content. That is, such chatbots are purposeful, provide information on request, which again is not a tour, but already implements part of it.

More about the capabilities and development of dialog agents in the articles [13, 14]. The authors analyze such architectural approaches to the construction of museum dialogue agents as machine learning, connection to knowledge graphs, understanding of natural language. The study emphasizes that the use of knowledge graphs is a key technology for conversational agents, but notes that modern software is not yet able to support natural everyday conversations with people.

From the analysis of recent research and publications, we see that the software for virtual tours does not currently exist. Existing systems rely on ready-made conversation routes or perform only a reference function. The development of such dialog agents does not require much effort, but is time consuming and based on a large body of text data. The Wit.ai, Google's Dialogflow, IBM's Watson, and other frameworks allow you to develop similar software, but are not at all designed to create a complex dialog system that is a virtual guide. Controlled or uncontrolled algorithms are used in machine-learning chatbots, segmentation and morphological analysis in natural language comprehension methods [13]. The development of software for virtual tours requires special information support, architecture using knowledge graphs and a combination of algorithms for machine learning, processing, understanding and generation of natural language.

The aim of the research is to improve the perception of works of art and the exhibition by visitors, through the implementation in the exhibition hall of a virtual guide who uses natural language processing techniques to form a tour of the exhibition, accompany the exhibition, guide and encourage visitors.

Presentation of the main material

Excursion is essentially a process in which the guide helps tourists to see the objects through which the theme of the tour is revealed, the guide gives the necessary information to understand the meaning of objects, helps to master the skills of self-observation and analysis of excursion objects [3]. The formation of the ability to see is divided into:

1. Aesthetic perception - the ability to see lines, colors, shapes, group them into complexes with the condition of perspective, light, air, angle.

2. Historical perception - the ability to find in the object characteristics and historical and cultural features, to see the evolution, the passage of time.

The model of interactive experience of visitors consists of three interacting contexts: physical (collection of structures and things presented by the exhibition), personal (unique experience and knowledge of a particular person), social (contact with other visitors, with a guide) [15].

Based on the model and definition of the tour as a process, we will form the main tasks of the guide [3]:

1. Choosing a topic.

2. Selection of literature and other sources of excursion material.

3. Selection and research of excursion objects.

4. Forming a map of the tour.

5. Drawing up of the individual text of excursion taking into account methodical receptions of carrying out excursions.

Let's define what are features at the automated virtual excursions. A virtual tour differs from a real one by displaying objects that visitors observe in cyberspace by means of computer graphics for self-analysis [16]. The advantages of this approach are accessibility, visibility, interactivity. From the above definition we see that in modern virtual exhibitions the role of the guide, as well as its implementation, is not considered. The new definition of a virtual tour offers: a combination of virtual space with simulated observation objects for self-perception and software of the dialog guide system for the implementation of the social context of the tour, focus and educational process.

To form the functional requirements for the tour software, we will consider such analogues of guides as works "Promobot" and "Pepper", chat-bot for the museum Casa-Museo Boschi Di Stefano, analogues of dialogue systems "Siri" and "Alice".

The robot "Promobot" [17] tells about the exhibits of the museum, answers the questions of visitors, using the information base and relevant sources of the Internet. Excursion from this work is a greeting, a tour of objects with information about the exhibits from the exhibition base, answers to questions, farewell to the opportunity to take a photo for memory. The Pepper robot [18] has perception modules, namely sensor sensors, LEDs and microphones, to recognize and interact with the person talking to him. The robot supports 20

degrees of freedom for natural and expressive movements, 15 languages, uses infrared sensors, bumpers, inertia unit, 2D and 3D cameras, as well as means for autonomous navigation. The tour is based on a similar principle as in the work "Promobot", but supplemented by emotional modeling, reaction to the mood and movements of people according to the algorithms for detecting facial emotions. The chatbot for the Casa-Museo Boschi Di Stefano recreates a conversation with a virtual character who creates a virtual adventure with tips from the exhibition halls [19]. The tour takes the form of a game, which allows visitors to gain research experience, but the support of the dialogue is implemented in the form of user choice of the answer, this guide also does not answer the question. The Siri Interactive Dialog System operates on a question-and-answer basis, based on context recognition and service delegation [20]. At the request of the user, the system performs the functions of the operating system itself, such as searching, creating documents, launching applications, which can be used in the web service of virtual art exhibitions. The Alice dialog-assistant system [21] also solves everyday tasks using Yandex services, supports dialogue on abstract topics using machine learning methods. The neural network of the system has been trained in a large selection of texts, including dialogues from social networks, which is why some users report cases of rude behavior and refusal to perform tasks. The possibility of abstract conversations must also be implemented in the tour software, taking into account the verification of the correctness of the data for the information base.

An architectural and algorithmic solution is proposed

From the study of analogues we can conclude that the introduction of the module of excursions to virtual tours can be implemented by means and methods of artificial intelligence, which work on dialogue systems-assistants and work-guides. The offered functionality of the automated system of virtual tour which is developed, adhering to the formed definition of virtual tour, is shown in Fig. 1.
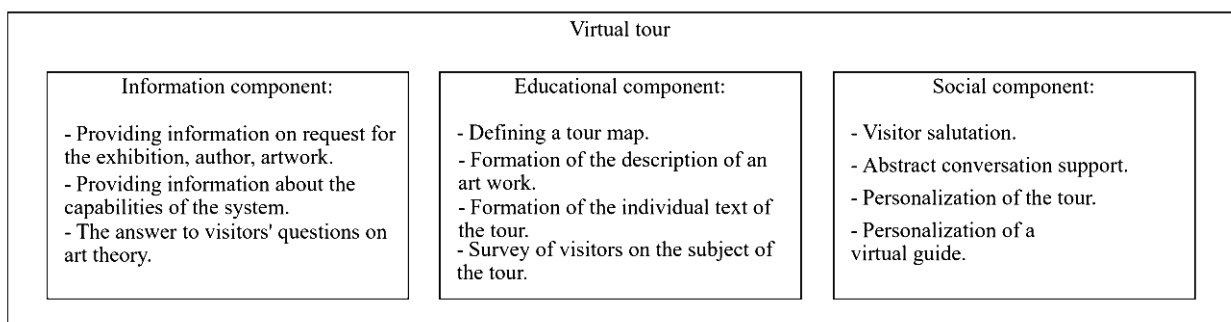
Virtual tour		
Information component: - Providing information on request for the exhibition, author, artwork. - Providing information about the capabilities of the system. - The answer to visitors' questions on art theory.	**Educational component:** - Defining a tour map. - Formation of the description of an art work. - Formation of the individual text of the tour. - Survey of visitors on the subject of the tour.	**Social component:** - Visitor salutation. - Abstract conversation support. - Personalization of the tour. - Personalization of a virtual guide.

Figure 1. Functional requirements for virtual tour software

To design the architecture of the system of organization and conduct of virtual tours, it is necessary to take into account the architecture of the web service of art exhibitions. Since most modern web services of virtual exhibitions are designed using PHP or JavaScript

frameworks, the first proposed architectural solution may be to place the dialog system module directly in the web service, for which it is necessary to explore the possibility of implementing a dialog system in JavaScript. The second proposed option for developing software for tours is to separate the software for tours to its own RESTful service. The second solution allows you to use Python for development, which implements many packages for working with natural language, but also requires the separation of the database of the web service itself. The architecture of the second proposed solution for the implementation of software for tours is shown in Fig.2.
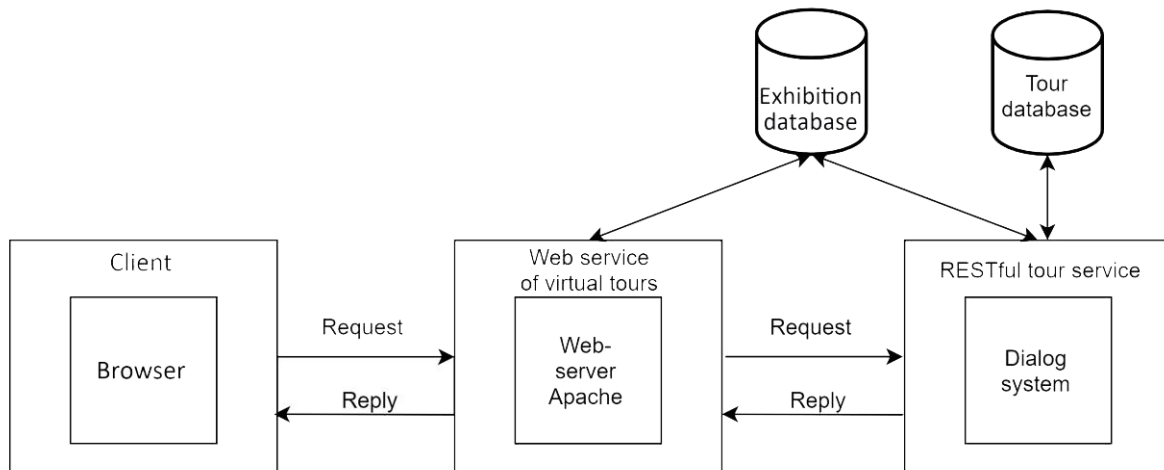

Figure 2. The architecture of the software package of web services
for organizing and conducting virtual exhibitions and tours

The proposed architecture allows you to encapsulate the logic of the guide from the web service of exhibitions, which simplifies its implementation. Distributed client-server architecture significantly reduces the load on the client's graphics subsystem, compared to the embedded JavaScript implementation, when loading and running NLP models is performed by a browser [22]. In a study of the possibilities of natural language processing in JavaScript, it was found that the download of the vector model of word representation required to represent the content can take up to 10 minutes if the model size is less than 800MB (for comparison, the original Ukrainian word2vec model weighs 7GB), which is unacceptable. This is not the only reason why it is proposed to choose a distributed architecture. It was found that there are the following most popular libraries and frameworks for natural language processing in JavaScript:

1. NLP.js - allows us to create a chatbot, by defining cues and answers, i.e. the text corpus of dialogues, which eliminates the implementation of additional system logic, such as the formation of the tour.

2. ml5.js - provides a text classifier and a model of vector word representation, but does not support the Ukrainian language, and a long time to load the model has already been mentioned.

3. tensorflow.js - contains text classifiers and a universal sentence decoder without the support of the Ukrainian language, as well as without the ability to retrain them on our own dataset. Has the functionality of building and training neural networks.

Summing up, it is determined that the basic principle of working with natural language in JavaScript is the creation of a neural network, so chatbots by JavaScript are a set of rules or a generative network in the dialog box [22]. For complex software with its own algorithms for forming the context of the dialogue currently has no means of implementation in JavaScript, namely, not identified the ability to implement morphological analysis to create knowledge graphs, the ability to work with models Glove, FastText, Word2vec, lemmatization, stemming, tokenization for normalization of the text. Therefore, preference is given to the decision to separate the tour service.

For interaction of services it is offered to choose REST architectural style, thus the web service of exhibitions needs to implement the graphic interface of the guide and algorithms of sending and processing of inquiries to service of excursions where it is offered to define the following controllers:

1. Initialization of excursions. After opening the virtual hall page, the web exhibition service sends the tour and user IDs to the web tour service. The system saves to the database of excursions information about the started session, creates graphs of knowledge on the excursion and its works, determines the map of the excursion, returns to the web service of exhibitions the identifier of the created excursion and the greeting text.

2. Visitor request. The web service sends a text request to the visitor with the tour ID obtained from the server in step 1. The system checks the context and status of the tour by ID, executes the necessary instructions in the dialog manager and returns the next step object to the web service. in the dialog box, the beginning of the tour, showing the picture by ID, the end of the tour. Algorithms for moving in the 3D space of the exhibition hall by work IDs must be implemented in the web service of exhibitions.

3. Completion of the tour. The system destroys all records in the database by the tour ID.

The dialog system of the web service of excursions can be implemented by the architecture of the following types [23]:

1. Rule-oriented systems, built by automatically deriving the rules on the basis of which decisions are made. The constructions of conditions and actions that are recognized by regular expressions or more complex methods of language recognition are prescribed. It consists of the following components: a base of rules, an interface of conclusions, which consists of compliance, conflict resolution, acts; and temporary working memory [24].

2. Neural network systems involve the use of neural networks to classify text according to user intentions, training generative models seq2seq based on dialog boxes to generate responses and more. Such an architecture allows you to handle intentions that were not used during network training.

3. Hybrid systems to solve the problem use more than one method of simulating intellectual activity [25]. That is, hybrid systems use both rules and machine methods.

For the operation of the dialog system of the virtual guide it is necessary to follow the instructions of the tour algorithm and at the same time determine the intentions of the user when he wants to get information, go to another job, finish working with the guide. Thus, it is necessary to implement a hybrid architecture of dialog systems.

Through the analysis of the subject area it is concluded that the logic of the virtual guide requires the following software components: dialog status tracker, dialog manager, intention classifier, tone classifier, generative network, components of SQL database (exhibition data), NOSQL database (knowledge base) , creation and processing of graphs of knowledge, formation of the text of excursion, definition of the map of excursion, set of skills. The following scheme of interaction of the user with a complex of the software of virtual excursions which is resulted in Fig. 3.
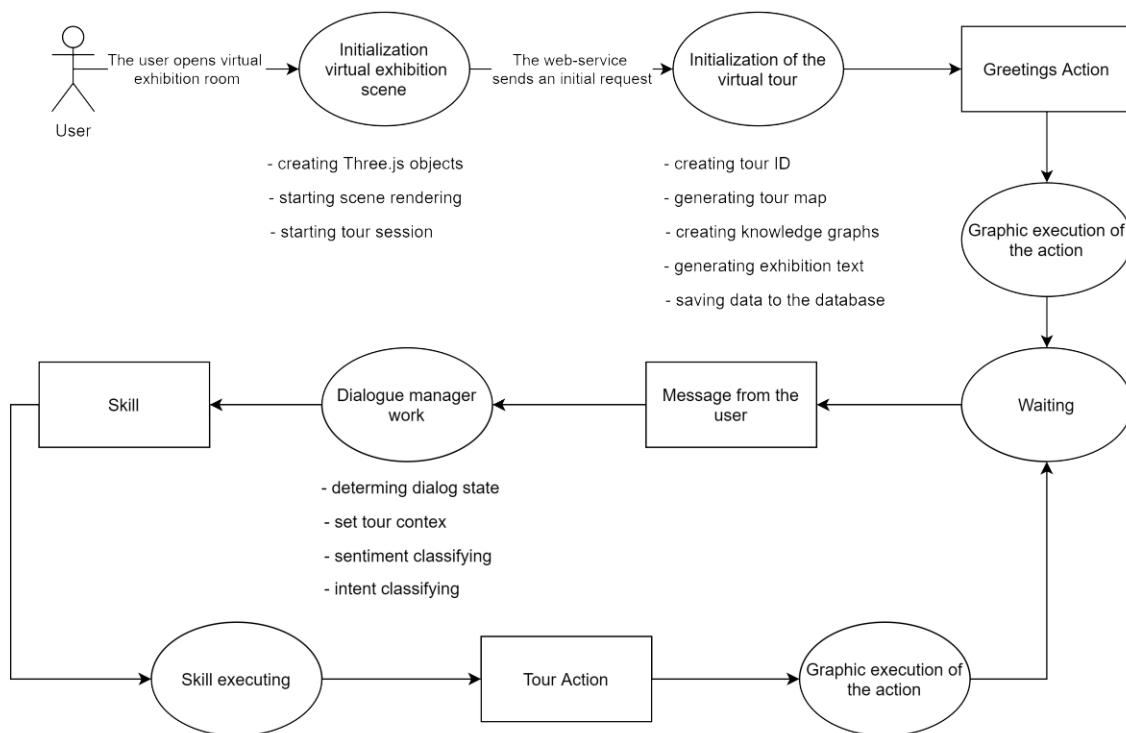

Figure 3. The scheme of interaction of the user with
a complex of the software of virtual tours

Consider the proposed mechanism of interaction: the user opens the page of the virtual hall of the selected exhibition in the web service of art exhibitions, the service renders graphics and sends a request to the start controller of the web service tours. The initiation of the tour includes the creation of a map of the tour, the creation of graphs of knowledge, the generation of the tour. Creating a map of the tour is proposed to do on the basis of a description of works of art, determining the order of display of works by semantic similarity. The proposed algorithm calculates a content vector for each job description using the FastText model of vector representation of words, which demonstrates results more accurate

than word2vec, Glove, Doc2vec [26]. The Euclidean metric formula is used to determine the percentage of similarity of vectors:

{\displaystyle d(p,q) = {\sqrt {p_{1} q_{1})^{2}+(p_{2} q_{2})^{2}+\dots+(p_{n} q_{n})^{2}}}={\sqrt {\sum_{k=1}^{n}(p_{k} q_{k})^{2}}}}}

$$d_{pq} = \sqrt{\sum_{i=1}^{n} \left(p_i - q_i \right)^2} \, , \qquad (1)$$

where p, q – points in n-dimensional space.

From the study of knowledge graphs it is determined that the most important for the construction are the nodes and edges between them. These nodes will be the entities present in the sentences. Ribs are relations that connect entities with each other. It is suggested to delete these elements using sentence grammar. The basic idea is to go through the sentences and remove the subject and object when and where they occur [27]. Creating knowledge graphs is performed using NLP tools such as sentence segmentation, parsing dependencies, pos-markup, entity recognition. It was found that for the Ukrainian language such a possibility is provided by the library morphological analyzer "pymorphy2", which is proposed to be used in algorithms. After analyzing the methodology of the excursion, it is determined that the tour should be built on the principle: not to provide a lecture description, and provoke self-analysis by paying attention to detail, making problematic issues, verbal tasks, imagination, abstraction [3]. Thus, the proposed algorithm of the tour consists of greetings, determining the purpose of the tour, a consistent review of works, evaluation of the exhibition, recommendations. The algorithm for reviewing a work of art can consist of a discussion of the title, author, details, quotations, history - depending on what information is contained in the column of the work. From the information base, the text is supplemented with phrases of logical transitions between works, questions to stimulate analysis and compassion.

The dialogue manager is responsible for conducting the tour and general work in the proposed system. The algorithm of its work is as follows: if the context of the dialogue does not fit the rules, the user's text request is passed to the classifiers. If the system is waiting for a positive-negative response, the request after normalization is sent to the key classifier, if the probability of the label is less than 80%, the request goes further to the classifier of intentions, the probability is less than 80% - in the generative seq2seq network. The implementation of the tone analyzer is possible in Count Vectorizer, Word Embedding, Pre-trained Embeddings, Convolutional Neural Networks, but the best result in the study (89.8% accuracy on the test set) showed a model of logistic regression through TF-Idf matrices. To recognize intentions (labels "functions", "about yourself", "start of the tour", "end of the tour", "recommendations", "evaluation", "to favorites", "note") it is proposed to implement a multi-class text classifier, possible variants of which :

1. KNN, a classifier of nearest neighbors, the algorithm of which assumes that such things are in close proximity to each other. If a data point is near another data point, it assumes that they both belong to similar classes.

2. BERT model. The BERT algorithm is based on the seq2seq model and transformers. The seq2seq model is a neural network that converts a sequence of words into another sequence and is able to connect words that seem important.

3. SGD, stochastic gradient decline. An approach to the establishment of linear classifiers and regressors for convex loss functions, such as vector support machines and logistic regression.

4. FastText-classifier. The softmax hierarchical layer is based on the Huffman coding tree, which uses shorter trees to represent more common classes and longer trees for more rare classes. The probability that this text belongs to a class is investigated by a deep search along the nodes in different branches.

Because the data sets are small in size, the best test result was shown by the SGD classifier (91% accuracy on the test set).

Information support for virtual tours, as determined by the analysis of the subject area, should contain data on the basic terminology of art, tour guide, functions of a virtual guide, a set of data for training classifiers and vector word representation models, a body of dialogues for training generative model. It is suggested to use the Brown Corpus of the Ukrainian language to train the model of vector representation of words, but for datasets of dialogues and classification the information support was collected independently from the manuals of art history and excursion business.

The practical result of the research

The proposed solutions for the implementation of virtual tour software were tested on the example of a virtual guide "Exi", which was integrated into the web service of organizing and conducting art exhibitions "Xolst", the implementation of which was investigated in [28].

RESTful tour service was developed using the Flask microframework. The framework contains a set of Werkzeug tools, as well as the Jinja2 template, has a minimalist framework for web applications, and deliberately provides only basic functions, which is why it was chosen. To interact with the tour server in the exhibition web service, the Ajax query algorithm is implemented taking into account the CORS-policy, which is supported by the Laravel framework, which was used in the development of the web service. The graphical interface of the virtual guide, the animation of the hall movement and the review of works were developed using the JavaScript language library "Three.js", which is used to create and display animated computer 3D graphics based on WebGL. The interface of the implemented software for excursions "Exi" integrated into the web service "Xolst" is shown in Fig. 4.

Experimental research

To verify the achievement of the goal of the study, an experiment was conducted in which 50 people took part, who were divided into the following groups: group "A" (10 - 16 y.o.); group "B" (16-22 y.o.); group "C" (22-30 y.o.); group "D" (30 - 40 y.o.); group

"E" (40 - 50 y.o.). There were 5 women and 5 men in each group. The participants of the experiment visited two virtual art exhibitions of the web service "Xolst". The same number of paintings was placed in each exhibition hall (9 works from the collection of fine arts of Gradobank [29]), the halls were the same in size and design. At the first stage of the experiment, participants visited the first exhibition unaccompanied by a guide, and then assessed their emotional environment on a scale from 1 (negative) to 10 (positive), and answered 5 test questions for the exhibition. In the second stage of the experiment, participants visited the second exhibition accompanied by the developed virtual guide "Exi", noted the emotional environment and took the test. The order of exhibitions for different participants changed. The results of the experiment are presented in the diagrams in Fig. 5.
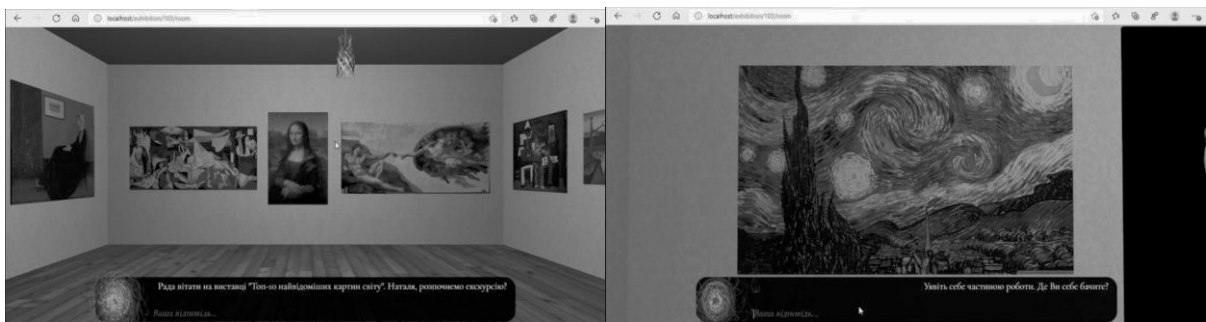

Figure 4. Graphical software interface
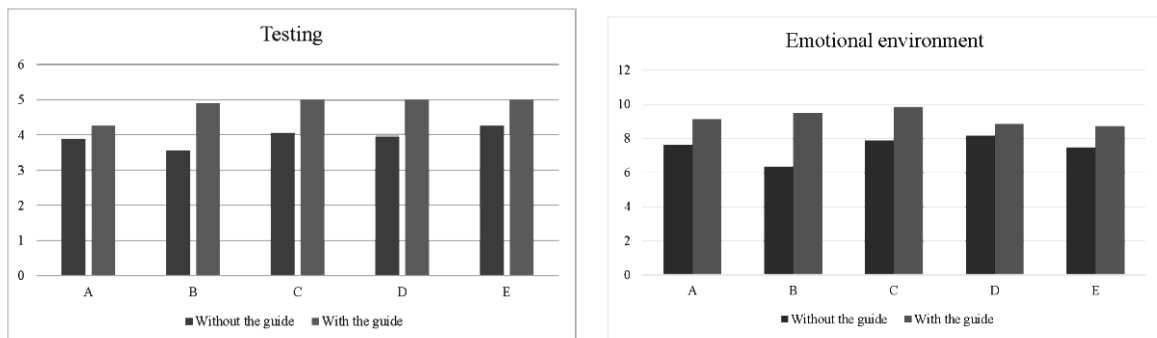for organizing and conducting virtual tours

Figure 5. Diagrams of the results of experimental research

The "Emotional Environment" diagram shows the relationship between the groups of participants and the arithmetic mean of the emotional environment obtained from the participants. Blue color - data of the first stage, unaccompanied by a guide. Orange color - data of the second stage, accompanied by a guide. The results show an improvement in the assessment of the emotional environment for all groups from an average of 7.48 to 9.2, an improvement of 17.2% when accompanied by a virtual guide. The biggest difference is observed in group "B" (16-22 y.o.), this is due to the fact that for this age group chatbots and dialog agents are a common form of information.

The "Testing" diagram shows the ratio of groups of participants and the number of correct answers to test questions for the exhibition. The results show an increase in the number of correct answers for all groups from an average of 3.94 to 4.83, an improvement of 17.88% when accompanied by a virtual guide.

It has been experimentally proven that a virtual guide increases the user's interest in the exhibition, improves the perception of works of art and creates a positive emotional environment.

Conclusions

Methods and means of software implementation for conducting virtual tours are investigated. A new definition of a virtual tour is proposed, which takes into account the role of the guide in the educational function of the exhibition. The architecture of the software complex of web services of the organization and carrying out of virtual exhibitions and excursions is offered. The approach to generation of the individual text of excursion with use of graphs of knowledge is offered. A virtual guide "Exi" has been developed, which improves the perception of works of art and the exhibition itself by visitors.

In the prospects of further development of information support, optimization of neural networks of classifiers, adding emotional coloring of the guide, research of intellectual image processing of works to expand artistic description, module of processing and generation of sound speech, improvement of separate components of virtual tours.

REFERENCES

1. Fromma J. More than experience? On the unique opportunities of virtual reality to afford a holistic experiential learning cycle / Fromma J., Radiantib J., Wehkingc C., Stieglitza S., Majchrzakb T. A., Brockec J. The Internet and Higher Education. 2021. Vol. 50. P. 1–14. DOI: https://doi.org/10.1016/j.iheduc.2021.100804 (accessed 20 October 2021).

2. Li Y. Art and Technology Exhibition under the Context of Artificial Intelligence. 3rd IFAC Workshop on Cyber-Physical and Human Systems. 2020. Vol. 53, No 5. P. 103–105. DOI: http://doi.org/10.1016/j.ifacol.2021.04.087 (accessed 20 October 2021).

3. Ємельянов Б. В. Екскурсознавство: навч. посіб. Москва: Радянський спорт, 2007. 216 с.

4. Indurkhya N., Damerau F. J. Handbook of Natural Language Processing (CRC Machine Learning & Pattern Recognition), 2nd Edition. Chapman & Hall, 2010. 702 p.

5. Kerpel O. I., Penko V. G. Development of software for the creation of the corpus of the ukrainian language and its use. Informatics and Mathematical Methods in Simulation. 2020. Vol. 10, No 1–2. P. 23–30. DOI: http://doi.org/10.15276/imms.v10.no1-2.23 (accessed 20 October 2021).

6. Carvajala D. A. L., Moritaa M. M., Bilmesab G. M. Virtual museums. Captured reality and 3D modeling. Journal of Cultural Heritage. 2020. Vol. 45. P. 234–239. DOI: https://doi.org/10.1016/j.culher.2020.04.013 (accessed 20 October 2021).

7. Gutowski P., Kłos-Adamkiewicz Z. Development of e-service virtual museum tours in Poland during the SARS-CoV-2 pandemic. Knowledge-Based and Intelligent Information & Engineering Systems: Proceedings of the 24th International Conference KES2020. 2020. P. 2375–2383. DOI: https://doi.org/10.1016/j.procs.2020.09.303 (accessed 20 October 2021).

8. Gutowski P. Development of Virtual Museums in Poland. Studia Periegetica. 2019. P. 9–32. DOI: http://dx.doi.org/10.26349/st.per.0027.07 (accessed 20 October 2021).

9. Bieszk-Stolorza B. Impact of the availability of gamified e-guides on museum visit intention / Bieszk-Stolorza B., Dmytrówa K., Eglinskieneb J., Marxc S., Miluniecd A., Muszyńskad A., Niedoszytkoe G., Podlesińskae W., Rostoványif A., Swachad J., Vilsholmg R. L., Vurzerf S. 25th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems. 2021. P. 4358–4366. DOI: https://doi.org/10.1016/j.procs.2021.09.212 (accessed 20 October 2021).

10. Vistisen P., Vashanth S., Rameshnath K. K. Applied Gamification in Self-Guided Exhibitions: Lessons Learned from Theory and Praxis. The potential for gamification in digital and analogue places. 2018. P. 29.

11. Miluniec A., Swacha J. Museum Apps Investigated: Availability, Content and Popularity. E-review of Tourism Research. 2020. Vol. 17, No 5. P. 764–776.

12. Gaia G., Boiano S., Borda A. Engaging Museum Visitors with AI: The Case of Chatbots. Museums and Digital Culture. 2019. P. 309–329. DOI: http://dx.doi.org/10.1007/978-3-319-97457-6_15 (accessed 20 October 2021).

13. Varitimiadis S. Graph Based Conversational AI: Towards a Distributed and Collaborative Multi- Chatbot Approach for Museums / Varitimiadis S., Kotis K., Pittou D., Konstantakis G. Applied Sciences. 2021. Vol. 11. DOI: https://doi.org/10.3390/app11199160 (accessed 20 October 2021).

14. Dale R. The return of the chatbots. Natural Language Engineering. 2016. Vol. 22, No 5. P. 811–817. DOI: https://doi.org/10.1017/S1351324916000243 (accessed 20 October 2021).

15. Falk J. H., Dierking L. D. The Museum Experience. Routledge, 2011. 224 p.

16. Александрова Є. В. Віртуальна екскурсія як одна з ефективних форм організації навчального процесу. Історія України. 2010. № 10. С. 22–24.

17. Promo bot tour guide. URL: https://promo-bot.ru/use-case/tour-guide/ (accessed 20 October 2021).

18. Robot Pepper. URL: https://www.softbankrobotics.com/emea/en/pepper (accessed 20 October 2021).

19. Interactive chat game for museum Casa-Museo Boschi Di Stefano. URL: https://www.facebook.com/casemuseobot/about/ (accessed 20 October 2021).

20. Siri – voice helper. URL: https://uk.wikipedia.org/wiki/Siri (accessed 20 October 2021).

21. Alisa (voice helper). URL: https://uk.wikipedia.org/wiki/Аліса_(голосовий_помічник) (accessed 20 October 2021).

22. Cai S., Bileschi S., Nielsen E. Deep Learning with JavaScript: Neural networks in TensorFlow.js, 1st Edition. Manning, 2020. 560 p.

23. Nakano M., Komatani K. A framework for building closed-domain chat dialogue systems. Knowledge-Based Systems. 2020. Vol. 204. DOI: https://doi.org/10.1016/j.knosys.2020.106212 (accessed 20 October 2021).

24. Rule-based system. URL: https://en.wikipedia.org/wiki/Rule-based_system (accessed 20 October 2021).

25. Колесников А. В., Кириков И. А. Методология и технология решения сложных задач методами функциональных гибридных интеллектуальных систем. М.: ИПИ РАН, 2007. 387 с.

26. Li S. Adaptive cross-contextual word embedding for word polysemy with unsupervised topic modeling / Li S., Pan R., Luo H., Liu X., Zhao G. Knowledge-Based Systems. 2021. Vol. 218. DOI: https://doi.org/10.1016/j.knosys.2021.106827 (accessed 20 October 2021).

27. Мачула О. В., Четвериков Г. Г. Обробка природної мови як частина штучного інтелекту. Public communication in science: philosophical, cultural, political, economic and IT context. 2020. Vol. 2. P. 70–73. DOI: https://doi.org/10.36074/15.05.2020.v2.27 (accessed 20 October 2021).

28. Кульбака Н. В., Федосова І. В. Розробка веб-орієнтованої системи організації та проведення художніх виставок у віртуальних галереях. Наука та виробництво : зб. наукових праць / ДВНЗ «ПДТУ». Маріуполь, 2019. Вип. 21. С. 184–193.

29. GradoBank art collection. URL: https://uk.wikipedia.org/wiki/Зібрання_(колекція)_образотворчого_мистецтва_Градобанку (accessed 20 October 2021).