LLM-Aided Museum Guide: Personalized Tours Based on User Preferences

Iva Vasic[1] [0000−0003−4081−0203], Hans-Georg Fill[2] [0000−0001−5076−5341], Ramona Quattrini[1] [0000−0001−5637−6582], and Roberto Pierdicca[1] [0000−0002−9160−834X]

[1] Polytechnic University of Marche, Ancona, Italy
[2] University of Fribourg, Fribourg, Switzerland

Abstract. The quick development of generative artificial intelligence (GenAI) techniques is a promising step toward automated processes in the field of cultural heritage (CH). The recent rise of powerful Large Language Models (LLMs) like ChatGPT has made them a commonly utilized tool for a wide range of tasks across various fields. In this paper, we introduce LLMs as a guide in the three-dimensional (3D) panoramic virtual tour of the Civic Art Gallery of Ascoli to enable visitors to express their interest and show them the requested content. The input to our algorithm is a user request in natural language. The processing tasks are performed with the OpenAI's Generative Pre-trained Transformer (GPT) 4o model. Requests are handled through the OpenAI's API. We demonstrate all the functionalities within a developed local web-based application. This novel approach is capable of solving the problem of generic guided tours in the museum and offers a solution for the more automatized and personalized ones.

Keywords: Large language models · Virtual museums · Extended reality.

1 Introduction

Amid COVID-19, museums started publishing content online urgently due to efforts to overcome the closure of the museums to prevent the spread of the virus [12]. Institutions were physically closed and the way of dealing with the situation was to expose the exhibits online. However, publishing content online is not enough, yet the solution to offer visitors the tours was in demand. As a response, many museums started offering immersive interactive virtual tours. Panoramic tours gained popularity because of the relatively simple process of acquisition and virtualization [15], [8], [14]. [20]. Moreover, tools for the panoramic tour creation in most cases offer user-friendly interfaces to facilitate the insertion of different kinds of panoramic images and embedding functionalities to them, becoming a paramount tool in the digital transformation of museums. Mostly, functionalities of virtual tours incorporate hotspots and floorplans for navigation, informative panels about the exhibits, and audio guides amongst others. In some cases, traditional chatbots are also involved in helping visitors find appropriate content as Chen [4] presented for the official online museum. However, the limitations and challenges of traditional chatbots may include false positives and negatives in responses, how users understand them, inefficient dialogues, and potential shortcomings in conversational quality [10].

The efficient alternatives to traditional chatbots are Large Language Models (LLMs) because of their capability to process natural language and generate new content easily. Since the release of ChatGPT in November 2022, many commercial and open-source LLMs have become available. A particular advancement seen in 2023 is their capability to process also visual content, both in terms of generating as well as interpreting it [5]. Some leading LLM models are, for example, LLaMa by Meta AI [17], an open-source foundational LLM which is suitable for various applications; Megatron-Turing NLG 530B [21], a product of the collaboration between Microsoft and NVIDIA; Claude developed by Anthropic [2], and Vicuna [16] from LMSYS, trained by fine-tuning LLAMA, and on top of which other models have been built, e.g. including MiniGPT [33]. Many of these models have shown impressive abilities across various domains, including healthcare, education, and even creative arts amongst others [23].

In terms of guiding visitors in virtual tours and providing them with the desired content, automatic methods are still insufficiently explored. The main challenges are the difficulties in large amounts of data management in museum databases, the same content for all visitors, and timely updates of the content. For small museums, it can be quite difficult to manage all the processes due to the lack of funding or expertise in web platform management and maintenance processes. To mitigate common issues and challenges, we propose an approach that incorporates LLMs to automatically guide users based on the requests. Moreover, we developed a web-based application that operates locally in the web browser.

Our paper is organized as follows. Section 2 showcases the previous work related to virtual museums with virtual guides. Our algorithm is explained in detail in Section 3, including the virtualization process and exhibit evaluation as the main processes. The developed virtual tour with an integrated guide for the Civic Art Gallery of Ascoli is detailed in Section 4, whereas the experimental results from the interactions within it are demonstrated in Section 5. The conclusion on the findings and usefulness of our approach, and our vision for future work is included in Section 6.

2 Background and Related Work

The use of chatbots in museums is an area of research and development that is gaining attention. In this summary, we will discuss various studies and articles that explore the implementation, evaluation, and potential of chatbots in museums. A new technological trend for museums is presented in an article proposed by [29], the MuBot museum chatbot platform. This platform allows museum visitors to chat with an "intelligent" exhibit and ask questions via text or voice, receiving written or spoken answers. MuBot uses advanced AI technologies such as Machine Learning, Natural Language Processing/Generation and Semantic Web, to learn and memorize new knowledge. The ultimate goal of the MuBot platform is to offer visitors an interactive and creative museum experience, able to tell the stories of the exhibited objects in a human and engaging way. The same authors in another work [28] examine a representative set of museum chatbots and platforms for their implementation. The authors present a systematic evaluation approach for assessing both the chatbots and the platforms. Additionally, they introduce a new approach to developing intelligent chatbots for museums, which emphasizes the importance of graph-based, distributed, and collaborative conversational AI systems for museums. The article highlights the use of knowledge graphs as a key technology for potentially providing unlimited knowledge to chatbot users, fulfilling the need for rich and machine-understandable content. Another paper by [24] aims to explore the evaluation of user experience with chatbot applications in museums and galleries. The paper introduces the principles of chatbots, their creation and testing, and explains the methods of evaluating user experience. The paper also lists the indicators that can be used to evaluate user experience with chatbots. A systematic review was conducted according to the PRISMA methodology to map the latest trends in chatbot development. Trichopoulos et al. [26] present an innovative approach to enhance the museum experience by using Generative Pre-trained Transformer (GPT) 4. By developing a museum guide based on GPT4, the authors aim to address the challenges that visitors face in navigating vast collections of artifacts and interpreting their meaning. Leveraging the model's natural language understanding and generation capabilities, the guide provides personalized, informative, and engaging experiences. To mitigate the problem that generated information may lack scientific integrity and accuracy, the authors propose incorporating human supervision and validation mechanisms. The same authors, in another work [25], suggest using large-scale language models as recommendation systems for museum visitors, but note that they cannot consider the temporal context in cultural environments like exhibitions and events. To address this, the study proposes adapting GPT4 into a context-aware recommendation system by incorporating contextual information and user instructions during fine-tuning. The resulting language models can provide personalized recommendations based on user preferences and contextual factors like location and time. User studies showed an improvement in visitor experience and engagement in museum environments. In the work of [18], the authors demonstrate how chatbots influence historical education and improve the overall experience in museums. The authors built three chatbot models based on embodiment and reflection factors and tested them at the National Museum of Korea. The results indicated that people with different learning styles interact differently with chatbots, and the behavior of visitors in the museum varies depending on the chatbot model used. This research provides important findings on the role of chatbots in education and engagement in museums. A research proposal by [7] explores how an evolving AI tool can be transformed into a storytelling tool that is in harmony with the museum path and allows for personalisation, but also respects the identity and peculiarities of the museum itself. The proposal aims to develop a chatbot to guide visitors within the museum, highlighting works of potential interest. The application context is the National Museum of Ravenna, characterized by a vast and heterogeneous collection that is difficult to access. Less recent, but noteworthy is the work of [11] that explores the application of AI in museums and galleries to improve the public's experience, with a focus on the development and use of chatbot technologies. A case study is presented that provides a practical analysis of a public development pilot project in Milan, involving four historic museums. The project's main aim was to find innovative and engaging ways to attract teenagers to visit these museums, using storytelling visualization and a convergence of chatbots and gamification platforms. Another study by [22] examines how the integration of popular chatbots and Augmented Reality (AR) multi-sensory technologies can create personalized museum visit experiences. The paper outlines the concept of a digital assistant-based application for museum visits. The visitor, equipped with AR technology, can ask questions about the exhibited objects and receive accurate and contextually relevant answers from the digital assistant, which can appear virtually as an avatar with accompanying AR multimedia information. The paper describes the implementation of a prototype of the application. While, the study of [27] proposes a custom Named Entity Recognizer (NER) developed for a chatbot in the Paleontology Museum of Athens with ChatGPT. Specifically, ChatGPT is "tricked" into acting as an NER by using a specific prompt that defines the entities and rules to follow. The results of the comparison provide useful insights into the capabilities, limitations, and applicability of these models in the context of chatbots. A preliminary study on the use of the social robot, named Pepper, as a tool to engage visitors during museum visits, has been presented by [3]. Pepper is equipped with a vision module that enables it to recognize visitors and the artworks they are looking at, as well as to estimate the visitor's age and gender. This data is used to provide recommendations on artworks that may interest the visitor during the visit. The effectiveness of this approach was tested in a research lab, and preliminary experiments have demonstrated the feasibility of this solution. The development of an intelligent conversational agent that enhances accessibility to information in a historical museum has been proposed by [6]. The virtual agent interacts with users in natural language and uses artificial intelligence to understand the Romanian language. The system was tested at the "Casa Mureșenilor" Museum in Brașov and received good levels of acceptance from visitors and museum staff. In their work, Wang et al. [31] present VirtuWander, an innovative virtual tour guide system that uses LLMs to transform user requests into various guidance-seeking contexts and facilitate multi-modal interactions. The system was tested in a user study within an immersive simulated museum, and the results show that it enhances the virtual tour experience through personalized communication and knowledgeable assistance. Ivanov [13] also proposes ExhibitXplorer, a distributed architecture service that uses geofencing, artificial intelligence, and microservices to provide personalized content in museums. By combining implicit and explicit segmentation of museum visitors and using the GPT API for content generation, the system offers a dynamic experience to different visitor segments, including researchers, students, casual visitors, and children. Tests conducted on an outdoor ethnographic museum showed that most visitors were satisfied with the way personalized content was delivered.

3 Our Algorithm

The core of our method is the evaluation of the exhibits based on their descriptions and the identification of their position within the panoramas in the three-dimensional (3D) space. The input of our algorithm is a user requirement in a natural language format about the content of interest. The output is a specific panorama and the content that matches this requirement. To achieve the desired output, each exhibit in all panoramas is embedded with a description that is interpreted with the LLM. To show the exhibit with a description that matches the requirement, we first need to identify its position in the panorama. This includes finding its spatial coordinates, including horizontal pan, vertical tilt, and the Field of View (FoV). Pan and tilt are mathematically defined as θ_x and θ_y angles for which the calculation is derived from mapping point coordinates from the Cartesian to the spherical coordinate system. This is explained in detail in the subsequent section. Figure 1 showcases all the steps in our algorithm.

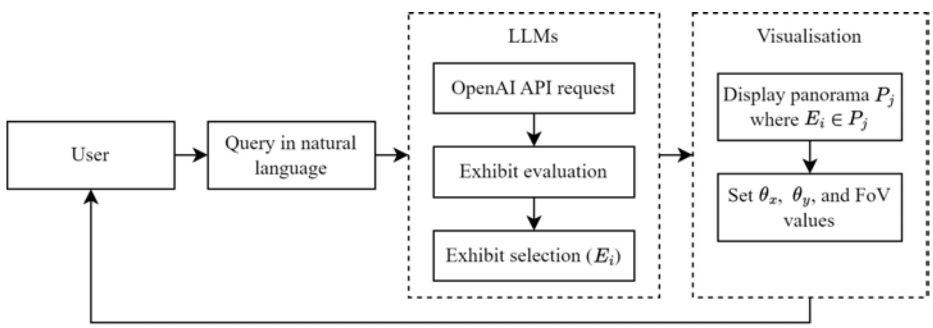

Fig. 1: The flowchart of the main processes within our algorithm

3.1 Virtualization Process

The first step toward the visualization of the panoramic tour is a virtualization process of panoramas. Panoramas are images that span 360°on the horizontal x-axis and 180°on the vertical y-axis in the spherical coordinate system. This along with the commonly known camera position in the acquisition phase, the calculation of the viewing angles in the corresponding spherical coordinate system is simple. The position of the camera for the acquisition is usually placed on the tripod at the height of h=1.7 m above the ground plane. From [30], angles θ_x and θ_y are calculated with the simple equation:

$$\theta_x = \frac{\pi}{\mathrm{H}} x \; ; \; \theta_y = \frac{\pi}{\mathrm{H}} y. \tag{1}$$

where x and y are horizontal and vertical axes of panorama equirectangular projection in $\mathbb{R}^2$ respectively, and H is its total vertical height in $\mathbb{R}^2$. These angles are sufficient for defining the direction in which the desired artwork should be viewed. Another important variable is FoV which is controlled with the zooming operations. Thus, each exhibit in the panorama is defined spatially by the viewing angles and FoV.

Semantically, each exhibit in a panorama contains an embedded description in the natural language format which is connected with its spatial features. Let E_i be the i-th exhibit in the panorama. The virtual tour comprises a set of panoramas $P = \{P_1, P_2, ..., P_j\}$ where $P_1, P_2, ..., P_j$ are the panoramas. Each panorama contains exhibits from the set $E = \{E_1, E_2, ...E_i\}$, where $E_1, E_2, ...E_i$ are the exhibits. We can define an exhibit as function $E_i = f(\theta_x, \theta_y, \mathrm{FoV}, \mathit{description})$ based on semantic and spatial features definitions.

3.2 Exhibit Evaluation

The input to our algorithm is a user request in natural language format, for instance: "I would like to see the painting that shows nature". Once the request is passed to the OpenAI API endpoint, all exhibit descriptions in JSON format are evaluated for relevance to the corresponding user request, with the score 5 being a perfect match, 4 being a very good match, 3 being a good match, 2 being an average match, 1 being a poor match, and 0 being not relevant. The study incorporates 4 paintings and 5 3D models with the corresponding descriptions and panoramas. The panoramas are indicated *nodes* in the application development which will be mentioned in the experimental result section. We use the GPT-4o model [19] for the natural language processing and relevancy assessment because of its advanced capabilities specifically in multilingual understanding. All the exhibit descriptions are provided by the curators from the Civic Art Gallery of Ascoli. The result of the evaluation output is the highest-ranked exhibit which is passed in the exhibit function along with the other spatial parameters. Note that evaluation of the artwork is an automatic process whereas the spatial values are defined and embedded in the corresponding panoramas with the contained exhibit. Once the algorithm processes all the exhibit parameters, the user is automatically provided with the relevant panorama with a focus on the matched exhibit. The user input allows for different languages which is beneficial for the understanding of a museum and ease of use among diverse users.

4 Web Application Prototype

Our local web application represents a virtual tour of the Civic Art Gallery of Ascoli. The presented version is built upon an already developed virtual tour that previously served mainly for museum digital content dissemination and consequently for user tracking in the virtual environments [30]. This version is updated to serve only for the museum visualization and LLM capabilities demonstration within the virtual tour. The architecture of the web application is defined with interactive elements such as buttons, pop-up menus, navigation maps, and hotpots for switch panoramas. The interactive content is available in both English and Italian, and the language can be selected on the virtual tour homepage. The web application source, primarily generated using the Pano2VR software tool for creating the virtual tour visualization [32], serves as a foundation upon which other functionalities are built. To integrate the GPT model for the requirement interpretation and painting evaluation, an HTML input form and buttons have been incorporated for the user input. Our application allows users to explore freely the Civic Art Gallery of Ascoli and to query for the desired painting simultaneously. Node.js [1] has been employed for managing data processing, server interactions, and backend logic. The interface with the main functionalities is shown in Figure 2.

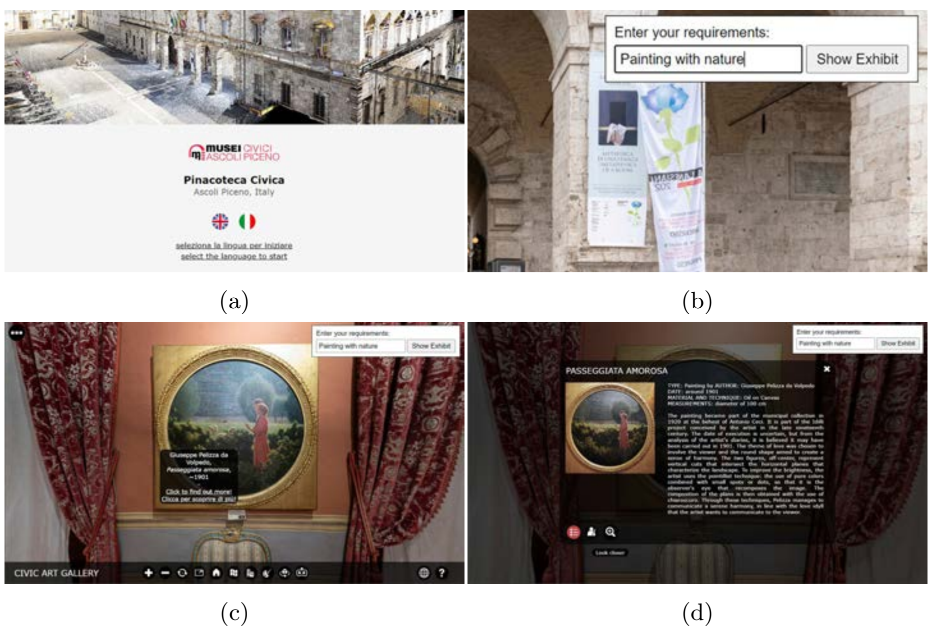

Fig. 2: Virtual museum application interface: home page of the virtual tour with the possibility of language selection (a), the input form for the virtual guide about the exhibit of interest (b), the exhibit that obtained the highest score according to the user input (c), and the interactive panel of the shown painting for more information (d).

The scenario from Figure 2 entails the demo of the process of our algorithm. The user is presented with the home page with the language options upon which the input form appears in the upper right angle of the screen. For this example, we prompt the guide to show the painting with nature. From the list of several paintings, it chose "Passeggiata Amorosa" ("Amorous Walk") which indeed depicts nature in the description file which can be found in supplementary material. The user is allowed for further interaction with the painting which can be obtained by clicking on it and consequently reading more detailed descriptions about the painting and the artist, or interacting with its gigapixel 2D representation. The virtual guide functionality does not restrict any other interaction within the virtual tour. Instead, it serves as an assistant, facilitating an interplay that implicitly enhances interaction with other features. In the subsequent section, we will demonstrate the effectiveness of the virtual guide with several examples.

5 Experimental Results and Discussion

Our research is primarily focused on the novel algorithm that incorporates LLM for exhibit evaluation and, as such, does not include a user study to evaluate its functionality. The prompts are carefully tailored to align with our specific dataset of exhibit descriptions. For example, there is no prompt on the glass sculpture as such an object does not exist in our database. In that case, our algorithm reports an unidentified object and the panorama remains the same. The extension of the exhibit database descriptions remains for further development in potential collaboration with the museum institution. To solve the problem of inconsistent response format across the outputs, we employed prompt-chaining [32].

The message to the system defines the main role of the model and parses the description dataset variable. Subsequently, the user prompt fetches the user request. The evaluation of the exhibits and defining the chosen painting tasks are included in the last two prompts respectively. From the response which contains a chosen painting, a custom JavaScript function within the application is used for parsing and extracting the exhibit node which is used for changing panoramas. We show several examples of the interactions within Table 1, highlighting the benefits of LLMs for the virtual museum. A complete code and prompts are contained in the supplementary material.

The results from the experiments are obtained from a single session on our local host browser. To evaluate the performance of our algorithm, we define several types of requests considering the descriptions of a few sentences for each exhibit. The advantage of the system is proven first through the multilingual types of prompts as the focus of the museum institution is on its public. To this end, the same prompt content is defined in Italian, Spanish, and Serbian language, asking about the painting with a serene landscape, vibrant colors,

Table 1: Prompts and selected exhibits by our model

No.	Type of Prompt	Prompt	Selected Exhibit
P1	Italian	Vorrei vedere un dipinto che raffigura un paesaggio sereno con colori vibranti e pennellate dinamiche. Il dipinto dovrebbe evocare una sensazione di tranquillità e armonia.[1]	Amorous Walk
P2	Spanish	Me gustaría ver una pintura que represente un paisaje sereno con colores vibrantes y pinceladas dinámicas. La pintura debería evocar una sensación de tranquilidad y armonía.[1]	Amorous Walk
P3	Serbian	Volela bih da vidim sliku koja prikazuje miran pejzaž sa živopisnim bojama i dinamičnim potezima četkice. Slika bi trebalo da izazove osećaj mira i harmonije.[1]	Amorous Walk
P4	Short	Antonio	Portrait
P5	Long	Rank the exhibits that feature marble sculptures from the 19th century, focusing on artistic techniques and historical context	The Shepherd Boy
P6	Theme-Based	Show the exhibit featuring a religious theme	Annunciation
P7	Specific Prompt	Show the best exhibits featuring 18th-century artifacts	Plates
P8	Contextual	Show me the exhibit that is a part of the Baroque collection	Annunciation
P9	Visitor Interest-Based	Suggest the exhibit that would interest children	Violin
P10	Typo-Embedded	sou mi d peinting wid pipl[2]	Amorous Walk

dynamic brushstrokes, and a sense of tranquility and harmony. The output was consistently "Amorous Walk" (Figure 3a).

The experiment has also been tested against the different prompt lengths. We suppose that each individual expresses themselves differently. The short prompt included only the term "Antonio" which is contained in the description of the painting Portrait (Figure 3d) by the artist Antonio Mancini. It is obvious to humans that the user would like to see this particular painting without thinking about the entire sentence. LLMs perform well in this case as well. A potential problem in such a case could be if there is more than one painting by the same

[1] English translation: I would like to see a painting that depicts a serene landscape with vibrant colors and dynamic brushstrokes. The painting should evoke a sense of tranquility and harmony.

[2] Correct prompt: Show me the painting with people

artist. Conversely, we prompt the model with a long prompt on ranking the exhibit featuring the marble sculpture from the 19th century. Only the Shepard Boy sculpture obtained the ranking, being the only one in the description that is indeed made of marble and dates from the requested period of time.

(a) (b) (c) (d)

(e) (f) (g) (h) (i)

Fig. 3: Visual representation of the used exhibits: "Amorous Walk" (a), "Saint Francis" (b), "Annunciation" (c), "Portrait" (d), " The Shepherd Boy" (e), "Plates" (f)(g), "Violin" (h), and "Reliquary" (i).

Theme-based prompt on the other hand yielded a score of 5 for several exhibits including paintings Annunciation (Figure 3c) and Saint Francis (Figure 3b), and artifacts Reliquary (Figure 3i) and Holy water bucket. The chosen and displayed exhibit was the painting Annunciation. We do not have many clues about the reason for such a decision, especially given the different outcomes over time. Therefore, the output is correct but the system requires additional engineering and adjustments to meet the specific museum requirements for displaying content.

We also prompt the system with the subjective task - "Suggest the exhibit that would interest children". Although all individuals are different, the system choice was quite deterministic by choosing Violin and The Shepherd Boy sculpture. We assume that the latter is directly connected to youth as the shepherd is a young boy resting in the field. The choice of Violin is, however, debatable because the other exhibits can be interesting to children as well. In any case, subjective requests require attention not only in terms of system engineering but also psychology which plays an important role in such decisions.

Lastly, we were curious about the capability of our model to perform on the erroneous content like in prompt 10. The correct version of the prompt should be "Show me the painting with people" for which we intentionally introduced typos. The system responded correctly, choosing paintings Amorous Walk, Portrait, Annunciation, and Saint Francis. A comprehensive list of evaluation values for all exhibits is included in Table 2.

Table 2: Exhibits and their evaluations according to the specific prompt

Exhibit	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Amorous Walk	5	5	5	0	0	0	0	0	0	5
Portrait	0	0	0	5	0	0	0	0	0	5
The Shepherd Boy	0	0	0	0	5	0	0	0	4	0
Annunciation	0	0	0	0	0	5	0	5	0	5
Plates	0	0	0	0	0	0	5	0	0	0
Holy water bucket	0	0	0	0	0	5	0	0	0	0
Violin	0	0	0	0	0	0	5	0	5	0
Saint Francis	0	0	0	0	0	5	0	0	0	5
Reliquary	0	0	0	0	0	5	0	0	0	0

The evaluation values indicate deterministic responses from the GPT-4o model which depend on diverse factors: the structure of instructions for the system, exhibit descriptions completeness and quality, prompt definition, and model parameters like "temperature". The former is introduced in our application as chain prompts, comprising several tasks in order to extract the precise results and avoid alteration in the response structure. A more suitable solution that we foreseen for future works is to incorporate a schema, ensuring that the model adheres to it, as demonstrated by Fill et al. [9]. The system prompts are short in our case which is relative among different museums. For this research, we incorporated short descriptions of about 3 sentences for each artwork followed by exhibit name, period, material, and authors amongst others. The evaluation could be improved if more content is provided to the system. We set the "temperature" parameter to 1 and "top_p" to 0.1 to balance between the randomness and predictability. Given the more theoretical nature of our research, we do not experiment with these parameters because our focus is primarily set to demonstrate the novel approach.

6 Conclusion and Future Work

In this paper, we introduced a novel algorithm for incorporating LLM as a virtual museum guide in the content-rich panoramic virtual tour. Our approach has the potential in helping museum experts adapt virtual museums according to the specific requirements and provide visitors with a more organized immersive experience than traditional ones. The virtual guide tool showed quality performance in the demonstrated experiment, becoming a suitable replacement for traditional chatbots. We demonstrated all the functionalities within a developed local web-based application. Moreover. this novel approach is capable of solving the problem of generic guided tours in the museum and offers a solution for the more automatized and personalized ones.

Although our algorithm has great potential in solving various tasks in the virtual museum system, there are still many challenges to be addressed and requirements to be met. For example, a complete application should incorporate other types of input such as multimedia and audio. GPT models allow for oral communication as well, addressing the needs of individuals with disabilities. Our future work encompasses integrating image recognition in addition to text input using LLM with vision capabilities and upgrading the virtual tour functionality, such as showing all relevant exhibits instead of only one. The important task is also to enable visitors to use the conversation agent for a more natural experience and explainable guide decisions. Moreover, the evaluation of our algorithm will be the final step in this process. Therefore, a comprehensive user study is envisaged to be conducted in order to obtain valuable feedback on the user experience.

References

1. Node.js. https://nodejs.org/, accessed: 2024-06-02
2. Anthropic: Claude (2024), https://www.anthropic.com/research, accessed: 2024-05-30
3. Castellano, G., De Carolis, B., Macchiarulo, N., Vessio, G., et al.: Pepper4Museum: towards a human-like museum guide. In: CEUR WORKSHOP PROCEEDINGS. vol. 2687, pp. 1–5. CEUR Workshop Proceedings (2020)
4. Chen, Y.T.: Chatbots for smart customer services on official museum websites. In: Hung, J.C., Yen, N.Y., Chang, J.W. (eds.) Frontier Computing. pp. 292–297. Springer Singapore, Singapore (2020). https://doi.org/10.1007/978-981-15-3250-4_34
5. Cui, C., Ma, Y., Cao, X., Ye, W., Zhou, Y., Liang, K., Chen, J., Lu, J., Yang, Z., Liao, K.D., et al.: A survey on multimodal large language models for autonomous driving. In: Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. pp. 958–979 (2024). https://doi.org/10.1109/WACVW60836.2024.00106
6. Duguleană, M., Briciu, V.A., Duduman, I.A., Machidon, O.M.: A virtual assistant for natural interactions in museums. Sustainability **12**(17), 6958 (2020). https://doi.org/10.3390/su12176958
7. Fabbri, F., Collina, F., Barzaghi, S., et al.: AI and chatbots as a storytelling tool to personalize the visitor experience. the case of National Museum of Ravenna. In: ExICE23 (2023)
8. Ferretti, M., DI LEO, B., Quattrini, R., Vasic, I., et al.: Creativity and digital transition in central Appennine. innovative design methods and digital technologies as interactive tools to enable heritage regeneration and community engagement.

In: Co-creating the Future: Inclusion in and through Design, vol. 2, pp. 187–196. eCAADe (Education and research in Computer Aided Architectural Design in ... (2022). https://doi.org/10.52842/conf.ecaade.2022.2.187
9. Fill, H.G., Fettke, P., Köpke, J.: Conceptual modeling and large language models: Impressions from first experiments with ChatGPT. Enterprise Modelling and Information Systems Architectures **18** (2023). https://doi.org/10.18417/emisa.18.3
10. Følstad, A., Taylor, C.: Investigating the user experience of customer service chatbot interaction: a framework for qualitative analysis of chatbot dialogues. Quality and User Experience **6**(1), 6 (2021). https://doi.org/10.1007/s41233-021-00046-5
11. Gaia, G., Boiano, S., Borda, A.: Engaging museum visitors with AI: The case of chatbots. Museums and Digital Culture: New Perspectives and Research pp. 309–329 (2019). https://doi.org/10.1007/978-3-319-97457-6_15
12. Gutowski, P., Kłos-Adamkiewicz, Z.: Development of e-service virtual museum tours in Poland during the SARS-CoV-2 pandemic. Procedia computer science **176**, 2375–2383 (2020). https://doi.org/10.1016/j.procs.2020.09.303
13. Ivanov, R.: ExhibitXplorer: Enabling personalized content delivery in museums using contextual geofencing and artificial intelligence. ISPRS International Journal of Geo-Information **12**(10), 434 (2023). https://doi.org/10.3390/ijgi12100434
14. Kersten, T.P.: 3D models and virtual tours for a museum exhibition of Vietnamese cultural heritage exhibits and sites. In: Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection: 7th International Conference, EuroMed 2018, Nicosia, Cyprus, October 29–November 3, 2018, Proceedings, Part I 7. pp. 528–538. Springer (2018). https://doi.org/10.1007/978-3-030-01762-0_46
15. Lee, C., Kim, J., Yi, H., Lee, W.: Viewer2Explorer: designing a map interface for spatial navigation in linear 360 museum exhibition video. In: Proceedings of the CHI Conference on Human Factors in Computing Systems. CHI '24, Association for Computing Machinery, New York, NY, USA (2024). https://doi.org/10.1145/3613904.3642952
16. LMSYS: Vicuna (March 2023), https://lmsys.org/blog/2023-03-30-vicuna/, accessed: 2024-05-30
17. Meta: Llama. Web Page (2024), https://ai.meta.com/llama/, accessed: 2024-05-30
18. Noh, Y.G., Hong, J.H.: Designing reenacted chatbots to enhance museum experience. Applied Sciences **11**(16), 7420 (2021). https://doi.org/10.3390/app11167420
19. OpenAI: Gpt-4o. https://openai.com/index/hello-gpt-4o/ (2024), accessed: 2024-05-30
20. Pirbazari, A.G., Tabrizi, S.K.: RecorDIM of Iran's cultural heritage using an online virtual museum, considering the Coronavirus pandemic. J. Comput. Cult. Herit. **15**(2) (apr 2022). https://doi.org/10.1145/3500925
21. Smith, S., Patwary, M., Norick, B., LeGresley, P., Rajbhandari, S., Casper, J., Liu, Z., Prabhumoye, S., Zerveas, G., Korthikanti, V., Zhang, E., Child, R., Aminabadi, R.Y., Bernauer, J., Song, X., Shoeybi, M., He, Y., Houston, M., Tiwary, S., Catanzaro, B.: Using deepSpeed and Megatron to train Megatron-Turing NLG 530B, a large-scale generative language model (2022)
22. Spadoni, E., Giussani, R., Carulli, M., Dozio, N., Ferrise, F., Bordegoni, M.: A personalized expert guide for the hybrid museums of the future. In: International Conference of the Italian Association of Design Methods and Tools for Industrial Engineering. pp. 261–272. Springer (2023). https://doi.org/10.1007/978-3-031-52075-4_30
23. Stanford Human-Centered Artificial Intelligence: 13 Biggest AI Stories of 2023 (2023), https://hai.stanford.edu/news/13-biggest-ai-stories-2023, accessed: 2024-05-30

24. Štekerová, K.: Chatbots in museums: Is visitor experience measured? Czech Journal of Tourism **11**(1-2), 14–31 (2022). https://doi.org/10.2478/cjot-2022-0002
25. Trichopoulos, G., Konstantakis, M., Alexandridis, G., Caridakis, G.: Large language models as recommendation systems in museums. Electronics **12**(18), 3829 (2023). https://doi.org/10.3390/electronics12183829
26. Trichopoulos, G., Konstantakis, M., Caridakis, G., Katifori, A., Koukouli, M.: Crafting a museum guide using ChatGPT4. Big Data and Cognitive Computing **7**(3), 148 (2023). https://doi.org/10.3390/bdcc7030148
27. Tsitseklis, K., Stavropoulou, G., Papavassiliou, S.: Custom named entity recognition vs ChatGPT prompting: A paleontology experiment. In: 2024 Panhellenic Conference on Electronics & Telecommunications (PACET). pp. 1–5. IEEE (2024). https://doi.org/10.1109/PACET60398.2024.10497008
28. Varitimiadis, S., Kotis, K., Pittou, D., Konstantakis, G.: Graph-based conversational AI: Towards a distributed and collaborative multi-chatbot approach for museums. Applied Sciences **11**(19), 9160 (2021). https://doi.org/10.3390/app11199160
29. Varitimiadis, S., Kotis, K., Skamagis, A., Tzortzakakis, A., Tsekouras, G., Spiliotopoulos, D.: Towards implementing an AI chatbot platform for museums. In: International conference on cultural informatics, communication & media studies. vol. 1 (2020). https://doi.org/10.12681/cicms.2732
30. Vasic, I., Pauls, A., Mancini, A., Quattrini, R., Pierdicca, R., Angeloni, R., Malinverni, E.S., Frontoni, E., Clini, P., Vasic, B.: Virtualization and vice versa: A new procedural model of the reverse virtualization for the user behavior tracking in the virtual museums. In: Extended Reality: First International Conference, XR Salento 2022, Lecce, Italy, July 6–8, 2022, Proceedings, Part II. p. 329–340. Springer-Verlag, Berlin, Heidelberg (2022). https://doi.org/10.1007/978-3-031-15553-6_23
31. Wang, Z., Yuan, L.P., Wang, L., Jiang, B., Zeng, W.: Virtuwander: Enhancing multi-modal interaction for virtual tour guidance through large language models. In: Proceedings of the CHI conference on human factors in computing systems. pp. 1–20 (2024)
32. Wu, S.: Research on the application of computer virtual reality technology in museum cultural relics exhibition hall. In: 2022 IEEE International Conference on Advances in Electrical Engineering and Computer Applications (AEECA). pp. 1049–1053 (2022). https://doi.org/10.1109/AEECA55500.2022.9919104
33. Zhu, D., Chen, J., Shen, X., Li, X., Elhoseiny, M.: Minigpt-4: Enhancing vision-language understanding with advanced large language models (2023)