Scientific Journal of the Ternopil National Technical University
2026, vol. 121, no. 1, pp. 56–64,
ISSN: 2522-4433 Print, ISSN: 2522-4441 Online
https://doi.org/10.33108/visnyk_tntu2026.01.056

Submitted: 2025-12-28 | Revised: 2026-01-30 | Accepted: 2026-03-24

A digital guide app for exhibitions: a case of Ternopil Regional Local Lore Museum

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Abstract: *The article analyzes approaches to creating digital information guides to support the activities of small museums of local importance. Recommendations have been developed for the implementation of a digital application based on industry standards in working with exhibits, an intuitive method of interaction with a visitor to a museum exhibition and providing user-friendly support for his individual track through the museum. The use of photogrammetric methods is proposed to create HD-textured 3D models of artifacts that are the central exhibits of collections in order to raise the museum's recognition, increase user interest and create a positive response from visitors. The practical implementation of the digitalization technology of historical and cultural heritage was carried out using selected exhibits from the Ternopil Regional Local Lore Museum as an example.*

Keywords: *information system; digitalization; cultural heritage; ontology; photogrammetry; 3D model; extended reality*

1. INTRODUCTION

In recent years, museums have been undergoing a process of active digital transformation, as modern digital technologies open up new opportunities for museum institutions to attract more visitors, provide more comprehensive informational accompaniment for rare and interesting exhibits, and more effectively preserve their collections [1].

Modern Ukrainian museums should seek a variety of ways to attract a new type of tourist who actively uses modern technologies, in particular the capabilities of mobile devices. The development of smartphone applications still has significant potential for personalizing the museum experience for users, integrating collections, exhibitions, and other offerings into a much wider range of scenarios for interacting with museum exhibits. The importance of using modern information systems to present historical and cultural heritage in the specific conditions of small museums and mobile support for selected exhibits was discussed, in particular, in the works [2–4]. At the same time, it is important to understand that focusing only on the technological and functional advantages of a mobile applications may not be sufficient, as such products have to be developed in line with user expectations and needs [5].

In study [6], the factors that visitors note as basic for gaining a positive experience of visiting museum exhibitions were analyzed, with the key ones among others being the accessibility and ease of use of the application. Visitors perceive multilingual support, the ability to work offline, an intuitive and effective user interface, free and multi-platform products, and the possibility to search for information about exhibits (by keywords) as essential and necessary features of a museum mobile application.

A smart museum app must contain a general description of the museum's thematic focus and structure, provide detailed and comprehensive information on how to get to the museum

(possible transport lines and means, route planning), as well as the museum's contact details and feedback system (chatbot, contact phone numbers, email, social media links, etc.). It is advisable to provide a system that allows users to book and/or purchase tickets and request a tour guide. Potential museum visitors may be interested in and attracted by the schedule of planned exhibitions and events, reviews and news reports about past events and exhibitions, as well as information about additional services (souvenir shop, café, interactive exhibition elements).

Support of a museum exhibition using a mobile application should be based on a detailed set of explanatory information packages for selected collections (a selection of important text information, photographs, video content describing the most interesting or special museum exhibits). A digital interactive map of the museum exhibition is essential, which should guide and help the visitor plan a route for viewing the exhibits. An audio guide with detailed information about selected elements of the exhibition is organically integrated into such a system, which helps to implement a narrative approach [7], adding, for example, interesting stories with virtual characters.

The authors [8] emphasize that museum guides which use the special capabilities of mobile platforms allow for the proper implementation of inclusive access to collections. At the same time, it is necessary to track the exhibits with which visitors interact most actively (sort of “centers” of the collections), since it is through them that such a visiting experience can be projected onto other institutions and recommended to encourage the distribution of free applications in museum accessibility programs. An analysis of a large number of mobile guides (with detailed statistics on functional features) for art museums around the world was recently conducted in [9], confirming a fairly high level of access to such applications and their stable, although somewhat limited, popularity among visitors. At the same time, there is a clear need to strengthen the integration of such tools with social networks, to introduce interactivity and gamification elements more widely, to ensure the possibility of automatic positioning of visitors in museum halls, and, most importantly, to expand the visitor experience beyond the physical space of the exhibition by means of augmented or virtual reality.

The study [10] notes that mobile applications currently viewed as an optimal tool for balancing the cultural depth of the museum sector and public participation in promoting activities aimed at preserving historical and cultural heritage (both tangible and intangible, i.e., traditions, social practices, crafts, etc.), thanks to the positive user perception of mobile technologies and applications, their interactive flexibility, and popularity. It should be emphasized that through in-depth analysis of user needs and behavioral characteristics, it is possible to ensure continuous optimization and improvement of the functionality of the digital museum applications in accordance with user activity, through changes in interface design, the creation of interaction scenarios, and the activation of social communication.

The integration of the mobile applications with the museum's traditional web resources is positively perceived by visitors, as it allows users to interact with content organized in a familiar way. At the same time, a growing interest is being generated by 3D virtual tours, the application of XR technologies (augmented/virtual reality), and the use of immersive technologies (a combination of projection tools, audiovisual effects, etc.). For example, the results of recent studies (see [11] and the review of XR applications in it) confirm the significant potential of augmented reality mobile applications to enhance the museum experience by increasing visitor engagement, providing a positive experience, and encouraging the continuous use of such information system. In addition, projection of digital content on real artifacts facilitates learning and, more importantly, stimulates an emotional connection between visitors and the cultural heritage they are viewing, helping to maintain visitors' attention and focus through interactive and visually appealing content.

2. METHODS

The work [12] notes that museum mobile applications, despite their different designs, have several basic properties that make them suitable for comparative critical analysis. These features include information about the institution for which the application was developed, content related to the exhibition, and auxiliary means of orientation in the area. Particular attention is paid to the need for proper testing by developers of GPS navigation in the museum, the ability to organize the database of exhibits according to the visitor's wishes, an intuitive interface with quick return to any exhibit, otherwise the experience of using such a museum assistant is rather negative.

To identify the explicit and latent needs and expectations of users of museum mobile applications, researchers [6] identified important components of an informational museum assistant that can be considered as recommendations regardless of the specifics of a particular country (see Table 1).

A detailed analysis of several dozen mobile applications for research centers and museums in North America and Latin America, conducted in [13], points to the key role of consolidated information about the features of the exhibition, presented in a form that is easy to perceive. In particular, a side menu list is important, which should be convenient and display all parameters on one screen without scrolling so that details are not hidden from the user (it is appropriate to use intuitive highlighted icons). The museum map should allow users to select objects of interest (exhibits, landmarks, etc.) and clearly display different floors in multi-story museums. The personalized recommendations feature is particularly effective, as it should resonate with visitors' interests, improving their experience by directing them to specific types of exhibits. Interactive UI elements should be used wisely to ensure intuitive user interaction.

Additional recommendations include, in particular, clear organization of content (images, texts, three-dimensional models, services, etc.), the ability to sort exhibits by topic. It is advisable to use short texts, internal search with hints, and high-quality images for information purposes. Navigation to previous screens should be convenient and intuitive, with the ability to create a user section called «Favorites».

It crucial to highlight the importance of implementing virtual and augmented reality, which can be a great culmination of the interaction that users expect from an exhibition, with broad creative possibilities. Digital 3D content plays a key role in modern conditions for updating the use of museum mobile guide applications, as it significantly and qualitatively renews the museum experience for visitors. The interactivity of 3D models allows users to explore exhibits from different angles and scales, which is impossible with traditional static displays (see, for example, the experience of the Ivan Puluj Digital Museum [14]).

Table 1. Basic components for a museum mobile application.

The museum as an institution	General description of the museum's thematic focus and structure
	Museum opening hours
	Interactive map (description) with directions to the museum
	Contact details, feedback option for visitors
	Ticket booking and/or purchase options
	Guide service booking options
	Schedule of upcoming exhibitions and events
	News about past events and exhibitions
	Information about additional services (souvenir shop, café, interactive exhibition elements)

Museum exhibition	Audio guide with detailed information about selected items in the exhibition
	Explanatory information packages for selected exhibits (a selection of important textual information and photographs)
	A photo gallery of the most interesting/unique museum exhibits
	Video content describing the most interesting/unique museum exhibits
	Interesting stories with virtual characters
	Integration with the museum's web resource
	Representation on social networks
	Virtual 3D tour
	Integration of XR technologies (augmented/virtual reality)
	Promotion of immersive technologies (combination of projection tools, audiovisual effects, etc.)
	Digital interactive map of the museum exhibition
Application accessibility	Multilingual support
	Offline mode
	Intuitive and efficient user interface
	Free access
	Search for information about exhibits (by keywords)
	Multi-platform compatibility

Visitors can examine details that are usually hidden when exhibited, or enlarge small elements for detailed study and analysis of texture. It should be noted that digital 3D content also provides access to artifacts that may be unavailable for viewing (due to their fragility, storage in reserves, or restoration), thus enriching the exhibition with virtual exhibits and complementing the museum's physical collection.

It is worth pointing out that photogrammetry techniques (see [15] for more details) can serve as a basis for creating 3D models of ancient historical artifacts, since this technology is non-invasive, allowing detailed models to be created without physical contact with fragile historical objects, thus preventing their damage. Modern approaches in photogrammetry ensure high accuracy of reproduction, capturing the smallest details of objects, including texture, colors, and features of the process of creating a cultural heritage object. Digital 3D models allow monitoring the condition of artifacts and the possibility of preservation even after the degradation or destruction of the originals. Once digitized, exhibits become accessible to researchers and the public around the world without the need for physical access to museum collections. Such models make it possible to conduct detailed analysis using computer tools, identify specific elements, or assist in the restoration of damaged parts of antiquities.

Virtual models can be used for educational purposes, making historical artifacts accessible to a wide audience through virtual museums and educational platforms. Digital models also facilitate collaboration between archaeologists, historians, restorers, and specialists from other fields. Based on fragments, it is possible to create complete reconstructions of objects or even entire historical complexes. Therefore, photogrammetry has become an indispensable tool in the modern museum industry and historical research, allowing for the preservation, study and distribution of humanity's cultural heritage.

3. RESULTS AND DISCUSSION

The rich collection of rare material artifacts and elements of spiritual heritage (numbering over 275,000 items), represented in unique collections from the Ternopil Regional Local Lore Museum (TRLLM), should be grouped both chronologically and thematically, taking into account the typology of artifacts (see Fig. 1). Thematic exhibitions are presented in

three basic departments of the museum: the department of nature (2nd floor), the department of ancient history (3rd floor), and the department of modern history (4th floor).

The detailed information gathered by [16,17] about the museum, its collections, and the structure of the exhibition needs to be distributed using modern information systems, such as a digital application, as it can help visitors plan their visit according to their personal interests and highlight the most important and interesting exhibits. In addition, an electronic mobile guide will help explain in detail the historical and cultural significance of individual thematic collections and key artifacts, contain important additional information that is often not provided in the captions to the exhibits, i.e., it can turn a simple tour of the exhibition into a full-fledged educational experience and contribute to better memorization of what has been seen (a tool to support decision in educational activities similar to the results of the work [18]).

In the context of digitalization historical and cultural heritage items, it is critically important not only to provide comprehensive information about existing museum artifacts in digital format for proper electronic accounting, but also to ensure the preservation of relevant textual and visual information entities. In addition, it is necessary to organize the exchange of such standardized information between entities in the museum sector and its appropriate presentation online for users, which will ensure controlled accessibility (for both museum curators and specialists, as well as ordinary visitors to museum exhibitions), promote digitalized heritage, and create conditions for the sustainable development of a digital society.

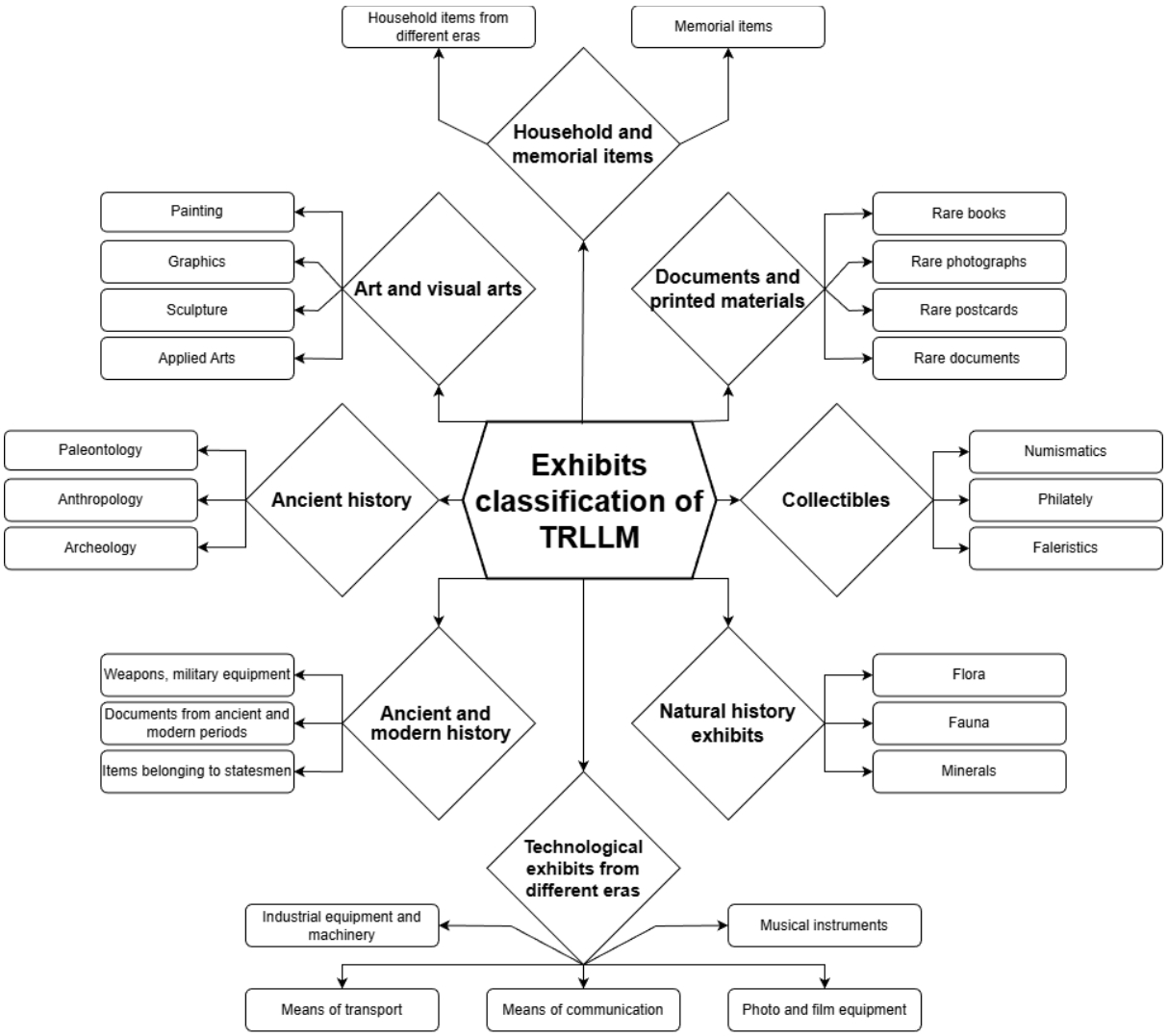


Figure 1. Exhibits classification of TRLLM.

Creating a «digital shadow» of a specific museum exhibit based on standard metadata helps solve a major problem in the museum industry – qualified access to the informational essence of an artifact. The use of an object-oriented approach in the context of integrating information from diverse sources about cultural heritage ensures the long-term preservation and further processing of digital data related to museum exhibits.

At the moment, work is still ongoing in Ukraine [19] on the implementation of ontological approaches for documenting information about historical and cultural artifacts, for example, based on CIDOC CRM [20]. Based on attempts to introduce digital museum cataloging [21], we note the importance of categorizing museum exhibits and establishing connections between them. First and foremost, it is important to identify entities (see class hierarchy [22] and the corresponding code identifiers), since the unique name of the artifact (E35) and the inventory number (E42) (there may even be several alternative names and digital identifiers) will allow for quick systematization and, if necessary, search for the exhibit in museum databases. The correspondence of an exhibit to a specific category or type (E55) allows for the initial classification of objects, which can then be supplemented with various links. Each artifact is characterized by a specific history of origin (geographical E53 and time E52 localization, production E12, acquisition E8, and transfer of custody E10) and has an attribute of authorship (E21 / E74).

For proper storage, transportation, installation, safe handling, and display, it is necessary to have comprehensive information about the physical characteristics of the exhibit, including its dimensions and weight (E54) and condition (E3/E14). A thorough understanding of the nature of the material (E57) will allow for the formulation of appropriate requirements for storage conditions (E7/E54 temperature and humidity conditions, lighting standards) and, if necessary, the need for restoration or even restrictions on display or research (E39/E30). Finally, classification in the context of technique or school of execution (E12/E29) is decisive for the art historical analysis of a museum artifact.

The scientific and cultural value of a museum exhibit has contextual historical significance (E5) for understanding the time period (E4) when the artifact was created and its ethnic cultural affiliation (E74). Often, unique exhibits (E13) have extremely interesting additional (E33) historical information, facts, involvement in historical events, etc., which adds weight to them and allows them to become the center of the collection, attracting visitors.

It is clear that a proper description of museum collections is a determining factor in controlling all aspects of exhibits, including sources of origin (E8), dates of registration (E52), detailed inventory description (E31, information about the last owner, expert assessment of condition), including the visual component (E36, photo and video materials, 3D models), which dominates in the modern era of innovative solutions in the field of augmented reality.

Therefore, it can be concluded that the use of information approaches similar to CIDOC CRM allows for clear and complete identification of exhibits in the museum system, compliance with legal norms, creates a set of attributes for further active research work, forms the basis for technical justification of storage conditions (taking into account the physical properties and condition of the exhibits). And, most importantly in the context of this work, it creates opportunities for exhibiting with full information support that is visitor-oriented.

In this article, with the aim of practical implementation of the above approaches, a demonstration version of the information guide of the Ternopil Regional Local Lore Museum has been developed. The emphasis is on enhancing the audio-visual accompaniment of the museum visitor's individual track, including the use of three-dimensional models of exhibits that are well-recognized central elements of the collections and are designed to create an unforgettable viewing experience of the rich exposition of the local lore museum.

Using photogrammetry process (which has proven itself well in the digitalization of small and medium-sized museum collections [23]), Five 3D models of unique exhibits, which

are the hallmark of the ancient history department of the Ternopil Regional Local Lore Museum, were created as part of a volunteer pilot project. To create each model, several hundred high-resolution photographs taken with a camera (Nikon D7000 SLR camera featuring a 16.2-megapixel Nikon DX CMOS sensor that provides natural-color, realistic imaging, paired with an AF-S 18–105 mm f/3 lens).

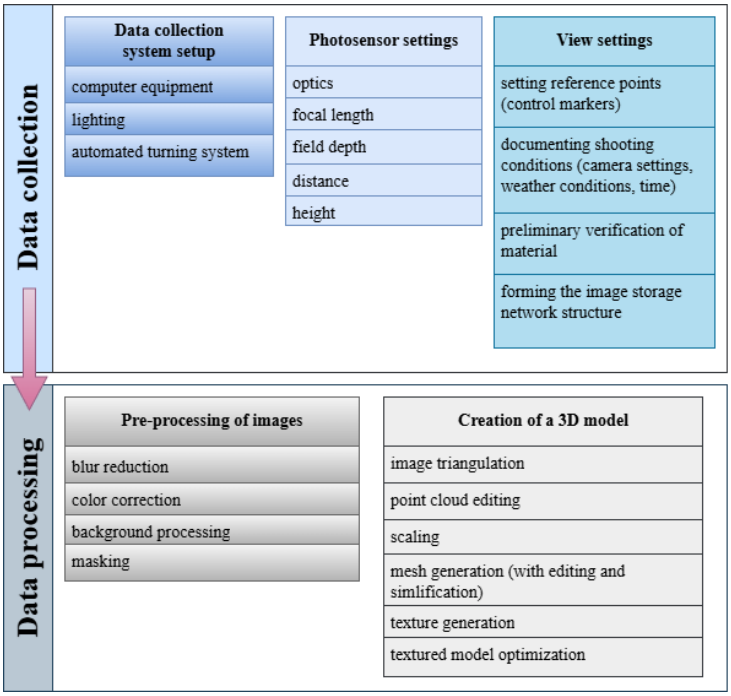
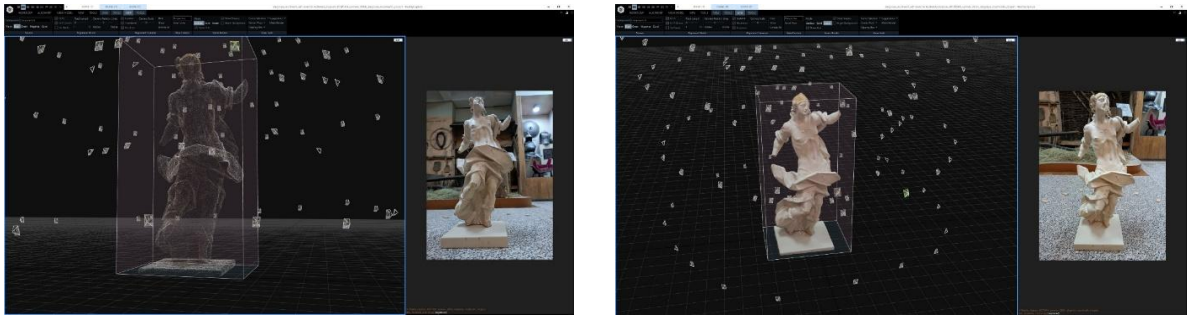


Figure 2. Diagram of the photogrammetry process for creating a 3D model of museum exhibits.

The photos of the exhibits were captured from an adjustable tripod through at least five circular passes taken at different height levels, using the Vivat D-26 automatic turntable system located in the Lightbox Puluz 60. Further processes involved taking sets of images with proper partial overlap of the visibility zones around the object ensuring that the software could perform accurate image triangulation (a schematic diagram of the workflow is shown in Fig. 2).

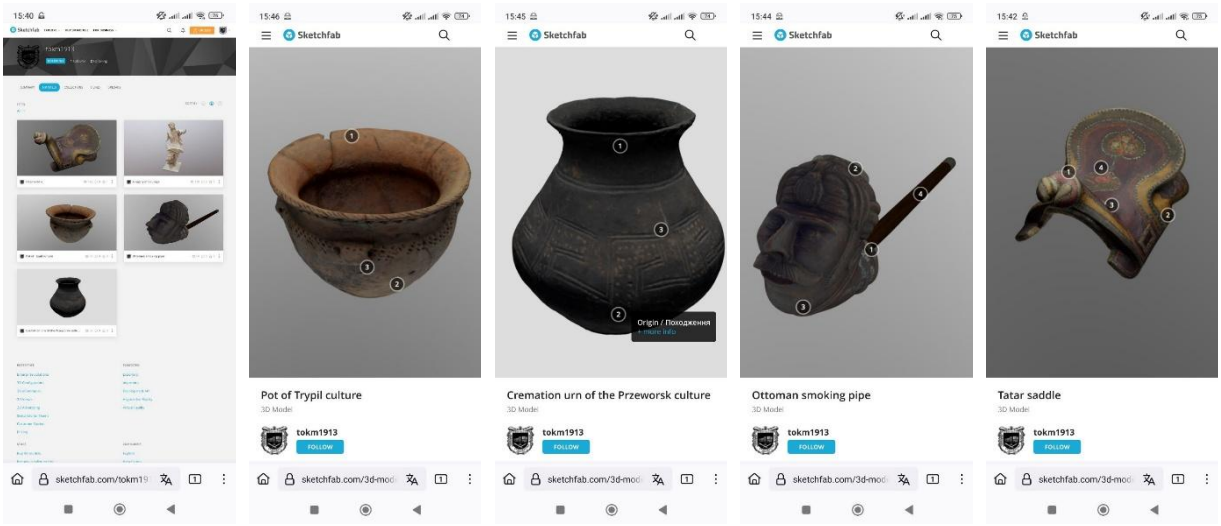
For reconstructing the exhibits in 3D, the RealityCapture was applied [24]. The workflow produces a dense point cloud capturing the full 3D structure of the exhibit, serving as the starting point for assembling the polygonal mesh. Afterward, a low-polygon model is created, and a texture of no less than 4K resolution is re-projected onto the high-polygon mesh (results presented in Fig. 3).



(**a**) (**b**)

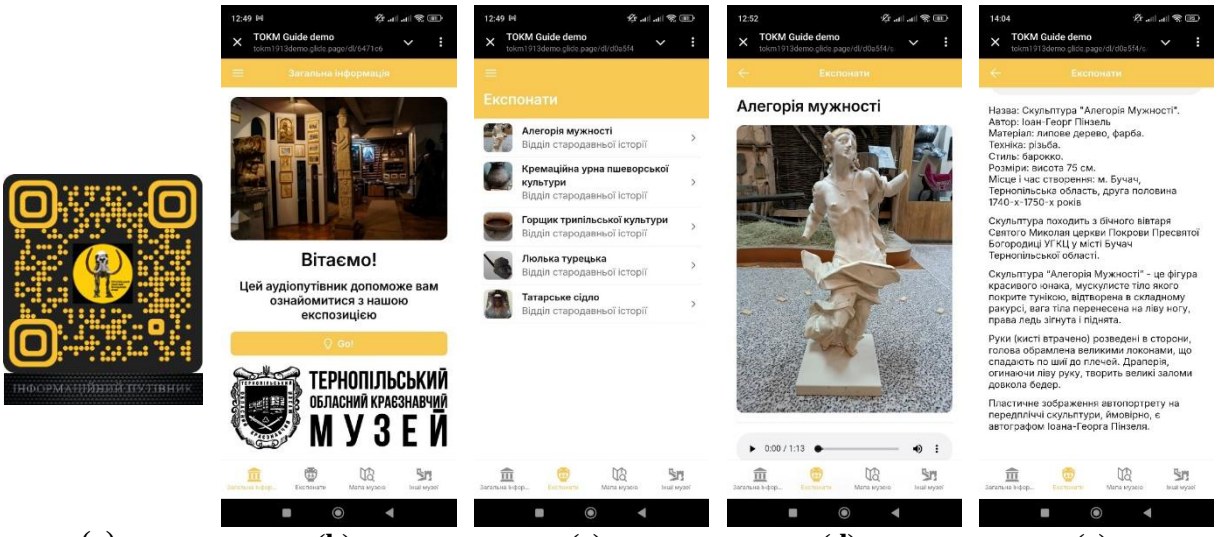
Figure 3. Creation of museum sculpture 3D model in RealityCapture: (a) work with a dense cloud of points; (b) texturing of the model.

The final models were exported to FBX format to be used as a part of the creation process of exhibition VR environment in Unity 3D. For web-based visualization, OBJ exports were prepared and uploaded to Sketchfab (see Fig. 4), and access to them was incorporated into the relevant platforms [25] using iframe elements.



(**a**) (**b**) (**c**) (**d**) (**e**)

Figure 4. Exposition of 3D models: (a) General view of the collection on Sketchfab; (b) Ceramic pot (Trypil culture); (c) Cremation urn (Przeworsk culture); (d) Ottoman smoking pipe; (e) Tatar saddle.



(**a**) (**b**) (**c**) (**d**) (**e**)

Figure 5. Demo version (Ukrainian localization) of the information guide for the Ternopil Regional Local Lore Museum on the Glide platform: (a) QR code for entry; (b) welcome page; (c) page with a list of featured exhibits; (d) Allegory of Courage; (e) information about the exhibit.

The demo version of the Ternopil Regional Local Lore Museum's information guide (see Fig. 5) was developed using the Glide platform, which has the advantage of providing the necessary functionality for a mobile or web application and allowing it to be administered by museum specialists with minimal programming knowledge. With a small project budget, which is critically important for small local museums, the platform allows you to quickly and efficiently design a guide, provides an appropriate level of control, registration, and personalized access, and the ability to receive feedback from users. Glide's flexible pricing policy creates opportunities to test different design forms and select the optimal template and application components. It is worth noting the ease of managing exhibit descriptions and media

content (photos of artifacts in various resolutions, audio accompaniment for exhibits, video inserts, the ability to embed iframes with 3D models, etc.), as well as the ability to quickly update information and monitor changes in real time.

4. CONCLUSIONS

1. Based on an analysis of approaches to creating digital information guides to support museum activities, the basic components of a mobile application designed for a small museum of local significance have been identified. The museum exhibition should be accompanied by a set of comprehensive information packages for selected artifacts (a selection of important text information, audio, photo, and video content) related to the most interesting museum exhibits that are the museum's hallmark. The key role of digital 3D content is in updating the use of museum guide applications is emphasized, which allows for a significant and qualitative improvement of the museum experience for visitors in the context of augmented and virtual reality.
2. Recommendations have been developed for the implementation of a digital application based on industry standards for working with exhibits, intuitive methods of visitor interaction with museum exhibits, and user-friendly support for individual museum tours. Short informative prompts, an intuitive interface, high-quality multimedia content with high resolution, multilingual support, integration with familiar museum web resources, and the ability to work offline help to make the digital guide an unobtrusive tool to assist museum visitors.
3. The paper proposes the use of photogrammetric techniques to create HD-textured 3D models of artifacts that are central exhibits in collections in order to raise the museum's profile, increase user interest, and generate positive visitor feedback. The detailed diagrammatic description of the key steps in the process of photogrammetry of museum artifacts provided in the paper will allow museum specialists to quickly master the technique of collection digitalization. The implementation of such approaches creates the possibility of interactive engagement with virtual museum artifacts and antiquities, supplementing them with additional informational content and allowing for the gradual formation of a digital museum archive. In such conditions, visitors are able to examine exhibits in detail without the risk of damage, and to understand their structure and historical and cultural context more clearly. We would like to emphasize the implementation of an inclusive approach to equal access to cultural heritage and broad opportunities for the creation of educational and scientific popularization materials.
4. As a practical case, this study implements the technology of digitalization of historical and cultural heritage using artifacts selected by experts from the exhibition of the Ternopil Regional Local Lore Museum (the «Virtual Touch» initiative on the customer's web resource). The ability to use no-code platforms and templates ensures the proper functionality of the mobile or web application and its administration by museum specialists with minimal programming knowledge. The ease of managing exhibit descriptions, additional multimedia content and quick information updates allow for an appropriate response to visitors requests and contribute to the transformation of museums into interactive spaces for interesting leisure activities, learning, and sparking interest for further research.

Author Contributions: Conceptualization: [Oleksandr Kramar]; Methodology: [Taras Kramar]; Software: [Taras Kramar]; Validation: [Taras Kramar]; Formal analysis: [Oleksandr Kramar]; Writing – original draft preparation: [Taras Kramar]; Writing – review and editing: [Oleksandr Kramar]; Supervision: [Oleksandr Kramar].

Acknowledgments: The authors of the article express their gratitude to the administration of the Ternopil Regional Local Lore Museum for significant support during the research.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability Statement: All data generated or analyzed during this study are included in this published article.

Declaration of Generative AI and AI-assisted technologies in the writing process: The authors declare that no generative AI or AI-assisted technologies were used in the writing of this manuscript.

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