

3D digitisation of artefacts and historical-cultural documents for viewing, interaction and information retrieval via QR Code: A Case Study of Tuyen Quang Provincial Museum, Vietnam

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Abstract: - In the context of digital transformation, the Fourth Industrial Revolution has profoundly impacted various sectors of society. The historical and cultural sphere is no exception. History and culture are considered the origins and reflections of the development of each nation and people, forming the spiritual foundation of society and creating the identity, strength, and sustainability of each nation. Today, historical and cultural values are often stored and preserved in national and provincial museums and historical sites. To enhance the historical and cultural value of artefacts and documents in these museums, research and application of advanced technologies are essential to improve preservation, accessibility, and public participation and experience. This paper proposes and implements a comprehensive solution for digitising artefacts and documents at the Tuyen Quang Provincial Museum using 3D modelling techniques combined with a QR code-based information retrieval system. The paper utilises photogrammetry, 3D scanning, and graphic software to recreate and reconstruct highly accurate digital replicas of actual artefacts. The digitised artefact models are integrated into a digital database and linked to QR codes for visitors to experience and interact in real time. The digitised artefact models will serve as the basis for building a system that allows for interactive exploration, discovery, and virtual exhibitions. The system has been installed at the Tuyen Quang Provincial Museum, and the results of the pilot implementation show improved accessibility, reduced physical contact with artefacts, and enhanced dissemination of traditional and cultural education. The proposed method contributes to the development of smart museums and sustainable heritage preservation in the digital age.

Key-Words: - Digital transformation, 3D modelling, museum digitisation, QR code, virtual museum, cultural heritage.

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1 Introduction

The strong development of digital technology/digital transformation has strongly impacted various fields of global social life and has contributed to reshaping many areas. This includes cultural heritage preservation and the promotion of the value of history and culture in museums today. Many countries have also shown interest in exploiting the strengths of digital technology such as 3D scanning, photogrammetry, and virtual reality (VR/AR), which have allowed relics and museums to digitise artefacts and documents and provide experiential access and interaction with historical and cultural content [1], [2]. These technologies contribute to innovating preservation methods by reducing physical contact with artefacts, improving

accessibility for remote users and a wider audience both domestically and internationally [3].

In the world, the field of cultural heritage has been studied and implemented by many developed countries using digital technology and digital transformation to support the digitisation, recreation, and restoration of documents, artefacts, relics, museums, etc., and thereby changing the way of promoting the value of cultural heritage. This solution uses 3D digitisation technology to digitise artefacts and documents based on 3D scanners, cameras, etc., and software technology to accurately build artefacts in terms of structure, geometry, and material characteristics so that they resemble the actual artefacts. Based on the 3D artefact models built and integrated into a virtual tour system,

users can display, observe, interact with, and experience the artefacts in a virtual environment, with features such as rotation and zoom-in/out [4], [5].

Technologies used to 3D model documents, artefacts, and spaces of relics and museums include Maya 3D, Unity 3D, and 3Ds Max. Technologies for building virtual tour systems and interactive experiences with 3D models of artefacts, documents, and virtual spaces of relics and museums, such as artificial intelligence (AI) and augmented reality (AR), are being integrated into museum and relic systems... to support enhanced user personalisation and interactive virtual experiences [6], [7]. Besides, the world also uses an integrated QR code system to look up information, images of artefacts, and documents [8].

Besides the achievements and progress in preserving and promoting the value of cultural heritage at relics and museums through 3D modelling of artefacts and documents using digital technology, this work still has certain limitations and shortcomings that need to be addressed with solutions for optimisation. Specifically:

(i): The above analysis shows that the studies in the above publications mainly focus on digital transformation technology solutions and the 4.0 industrial revolution, which are mainly implemented in developed countries in large museums and relics (national relics, special national relics...) with good and complete resources and infrastructure [9]. (ii): Most museums have not paid much attention to 3D digitisation, information retrieval and experience, 3D artefact interaction, and virtual museum experience space. In particular, there has been little focus on integration with simple access mechanisms, QR code-based systems [10]. (iii): Interactive systems, experiences, and information retrieval of 3D artefacts and documents and virtual museum spaces are only focused on deployment at large museums, meeting human resources and technological infrastructure requirements, as they require large financial resources to deploy and operate the system. Thus, small museums and relics lacking human resources and financial resources have not been able to implement many [11].

In recent years, digital transformation in Vietnam has been strongly implemented and applied to all aspects of social life. The cultural heritage sector has received significant attention, particularly the digitisation of cultural heritage in museums from the central to local levels, encompassing the digitisation of documents, artefacts, and the entire museum space. However, to date, the results of digitisation, the creation of virtual spaces for museums, the digitisation of artefacts, and the assignment of QR codes to artefacts and documents remain at less than 20 museums out of ap-

proximately 200 nationwide. Furthermore, the existing digitisation efforts in museums utilise different, fragmented technologies, lacking a comprehensive, synchronised, open, and integrated solution. Some museums still rely on traditional, mobile exhibition methods. This leads to limited access to information for the public, low interaction, and insufficient participation from young people.

From this context, the paper will focus on researching and proposing solutions using digital technology to build a process for 3D digitisation of artefacts and documents, and integrating QR Code identification for each artefact and document to support people in conveniently searching, displaying, and interacting with 3D information and artefacts. The paper will focus on researching and making the following main contributions:

- + Propose a 3D digitisation process for historical and cultural artefacts and documents at the Museum.
- + Develop a dataset of 3D models and descriptive information for each artefact and document, and assign QR codes to support information retrieval, interaction, and user experience.
- + Conducted a pilot study at Tuyen Quang Provincial Museum.
- + Introduce a new and open approach to the preservation and promotion of cultural heritage values for museums and other historical sites nationwide.

2 Literature Review

2.1 3D Modelling of Cultural Heritage

To digitise cultural heritage such as artefacts, documents, as well as museum and monument spaces, there are many approaches today. One of the commonly used methods is to use 3D cameras and scanners to capture images, materials, structures, and dimensions of real artefacts, including the space or location of monuments and museums [1], [4]. Previous studies have demonstrated that 3D reconstruction, restoration, and modelling significantly improve the quality of cultural artefacts, thereby enhancing the effectiveness of their long-term conservation and preservation [5]. Furthermore, the integration of 3D scanning and photogrammetry has been shown to be an effective approach for capturing artefact geometry and reconstructing highly detailed 3D models for virtual museum applications [12].

However, the use of technologies such as 3D scanners... has had drawbacks, namely the large amount of data generated, which has affected the speed of processing, simulation, or virtual tours. To overcome

these limitations, several studies have proposed methods to optimise 3D artefact scanning and post-processing workflows. Advanced reconstruction techniques based on machine learning have been shown to improve model accuracy and reduce noise during the scanning process; however, these approaches often require substantial computational resources [13].

2.2 Digital technology in the field of virtual museums

Museums play a vital role in preserving, safeguarding, and promoting the cultural heritage of each nation, including Vietnam. In recent years, museums have increasingly adopted digital technologies to improve heritage conservation and enhance public engagement through more interactive and accessible services. Commonly applied technologies include virtual reality (VR), augmented reality (AR), artificial intelligence (AI), Maya 3D, and Unity 3D, enabling users to experience cultural heritage in more immersive and realistic ways [3].

Numerous studies have demonstrated the effectiveness of digital technologies in developing virtual museum systems and enriching visitor experiences. Interactive support systems, real-time virtual environments, and virtual museum simulations have been shown to improve visitor engagement and accessibility by providing immersive and interactive experiences [6]. Furthermore, the integration of 3D scanning technology with interactive 3D environments has enabled the development of virtual museum tour systems that further enhance user interaction and accessibility [9].

In addition to VR and AR technologies, artificial intelligence has been increasingly employed to improve user interaction and personalise museum services. AI-based approaches have demonstrated the potential to analyse visitor behavioural data and provide adaptive, personalised user experiences [2], [13], [14]. Nevertheless, the application of AI in virtual museums remains challenging because it typically requires large-scale datasets, high computational resources, and advanced infrastructure, which may exceed the technical and financial capacities of many local and small museums.

2.3 Assigning QR code identifiers for information lookup

QR code is a type of code used to store information for the purpose of accessing, searching, and learning about a particular object. This article uses QR codes to store and search for information about artefacts and historical-cultural documents. Nowadays, both globally and domestically, QR codes have been widely

used in the commercial field, including in research. Scientists have used them to enhance the ability to store, search, and interact with multimedia data (information, images, audio, and 3D models...) [9], [10]. The use of QR codes offers many advantages, such as simplicity, no technical input, no high-tech and expensive technology, and suitability for museums and relics with limited resources.

However, research still points out the limitations of QR codes, such as not fully integrating with modern digital data content like 3D models, because QR codes still appear as an independent tool.

2.4 Research Problem

A field survey at the Tuyen Quang Provincial Museum regarding digital transformation activities, the application of advanced technology to 3D digitization of artifacts, documents, and museum spaces, and the use of QR code-based information retrieval technology, revealed that the Tuyen Quang Provincial Museum has not yet exploited or applied 3D digitization technology to artifacts, documents, and museum spaces, nor has it applied QR code technology to support the storage and retrieval of information on artifacts and museum attractions. This is one of the remaining limitations that the Tuyen Quang Provincial Museum needs to address and propose effective solutions for applying digital technology to support the storage and preservation of cultural heritage and promote its value in the future, contributing to improved efficiency.

3 Research Methodology

3.1 Research Technology Basis

To create 3D models for artefacts, documents, and virtual spaces in museums, several basic approaches are commonly used:

- + Modelling artefacts, documents, etc., based on technologies such as cameras and 3D scanning. This method is effective for representing objects as discrete pixels, facilitating image processing. However, this method has certain limitations in displaying, simulating, and interacting with images and the angles of the artefacts.

- + Modelling artefacts, documents, or museum spaces using basic geometric shapes such as points, lines, polygons, cones, cylinders, circles, etc., to adjust and change attributes to create the desired 3D models. This method is more suitable for 3D modelling and allows for flexible manipulation as desired.

To create 3D models of artefacts, several graphic software tools are used, such as Maya, 3Ds Max, and Blender.

+ Maya and 3Ds Max offer advanced capabilities for modelling and rendering.

+ Blender provides a flexible, open-source alternative suitable for many applications.

+ Other tools such as ZBrush (digital sculpting) and SketchUp (architectural modelling) are also used depending on specific requirements. In this study, a combination of Maya and 3Ds Max is applied to leverage their unique strengths in the modelling and rendering process to create the necessary and appropriate file formats.

The process of creating 3D models of artefacts typically uses the following main techniques:

- Modelling techniques, defining the geometric structure of the object.

- Rendering techniques, applying materials, lighting, and visual effects.

- Animation techniques, motion simulation, and dynamic behaviour.

In this, 3D modelling plays a crucial role, serving as the foundation, similar to building a "skeleton". Rendering techniques are used to add and overlay detailed materials onto the surface of the object, and animation techniques create movement and interaction for the object within the virtual environment.

3.2 Several methodological methods were used to build 3D models of artefacts at the Tuyen Quang Provincial Museum

3.2.1 Problem Formulation

Let an artefact be denoted as A. The objective is to construct a digital 3D model MMM such that:

$$M=F(I, D) \quad (1)$$

where:

1. $I=\{I_1, I_2, \dots, I_n\}$ is the set of multi-view images
2. D is metadata (geometry, scale, material properties)
3. F is the reconstruction pipeline

The goal is to approximate the real-world geometry G of the artefact:

$$M \approx G \quad (2)$$

subject to:

1. Minimising reconstruction error
2. Optimising rendering performance

Image Acquisition and Preprocessing

Each captured image I_i is modelled as:

$$I_i=S_i+N_i \quad (3)$$

where: S_i : true signal (artefact features).

1. N_i : noise.

Noise Reduction

Noise is reduced using filtering:

$$\hat{I}_i=H(I_i) \quad (4)$$

where H is a filter (Gaussian, median, or high-pass).

Image Enhancement

Edge sharpening:

$$I'_i=I_i+ \lambda.\nabla^2 I_i \quad (5)$$

where: ∇^2 : Laplacian operator; λ : sharpening coefficient.

Feature Extraction

Keypoints are extracted: $F_i=\{f_{i1}, f_{i2}, \dots, f_{ik}\}$ using SIFT/SURF-like descriptors.

3.2.3 3D Reconstruction via Photogrammetry

Feature Matching

For images I_i and I_j , feature correspondences are:

$$C_{ij}=\{(f_{ik}, f_{jl})\} \quad (6)$$

Camera Pose Estimation

Camera projection matrix:

$$P_i=K_i[R_i| t_i] \quad (7)$$

where:

1. K_i : intrinsic parameters
2. R_i, t_i : rotation and translation.

Triangulation

3D point X is computed from correspondences:

$$X = \operatorname{argmin} \sum_i \|x_i - P_i X\|^2 \quad (8)$$

Resulting in a **point cloud**: $P=\{X_1, X_2, \dots, X_n\}$

3.2.4 Mesh Generation and Optimisation

1. Surface Reconstruction:

From point cloud P , a mesh is generated:

$$M=(V, E, F) \quad (9)$$

where: + V : vertices

+ E : edges

1. F : faces

Mesh Simplification

To reduce complexity:

$$M'=\operatorname{Simplify}(M, \tau) \quad (10)$$

where τ is the reduction threshold.

Smoothing

Laplacian smoothing:

$$v'_i=v_i+\alpha \sum_{j \in N(i)} (v_j - v_i) \quad (11)$$

3.2.5 Texture Mapping:

Texture mapping assigns image data to mesh surfaces.

UV Mapping

Mapping function:

$$T:(x, y, z) \rightarrow (u, v) \quad (12)$$

Texture Optimization

Minimise distortion:

$$E_{texture} = \sum_i \|T(v_i) - t_i\|^2 \quad (13)$$

3.2.6 QR-Based Information Integration

Each artefact is assigned a unique identifier: $ID_A \in Z$

QR code generation:

$$QR_A = Q(\text{URL}(ID_A)) \quad (14)$$

When scanned:

User $\rightarrow QR_A \rightarrow \text{Web}(ID_A) \rightarrow \{M, \text{Metadata}, \text{Media}\}$

4 Results and discussion

Based on the above analysis of the current practices for preserving, storing, and promoting the historical and cultural value of artefacts and documents at the Tuyen Quang Provincial Museum, this section presents the results of the digitisation process, from artefact data acquisition and 3D modelling to noise reduction, texture mapping, and the final integration of completed 3D artefacts into a web-based 3D system. The system supports artefact preservation, public dissemination, and information retrieval through QR codes. The following figures and analyses illustrate the outcomes of the artefact digitisation process (See details in Figure 1 and Figure 2):



Fig. 1: 1Create 3D models using scanners

Source: created by the authors

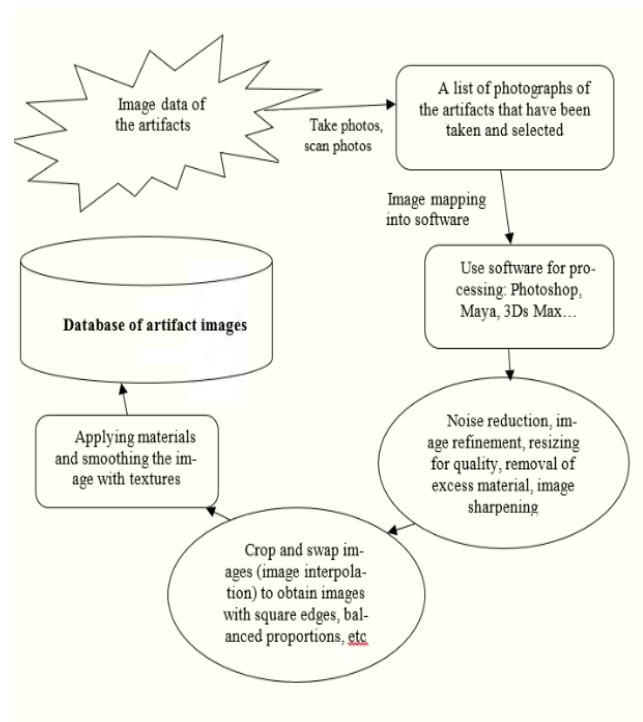


Fig. 2: 23D artefact digitisation process

Source: created by the authors

The figure 3 below illustrates the process of mapping the selected images into the image-processing software for enhancement and sharpening:

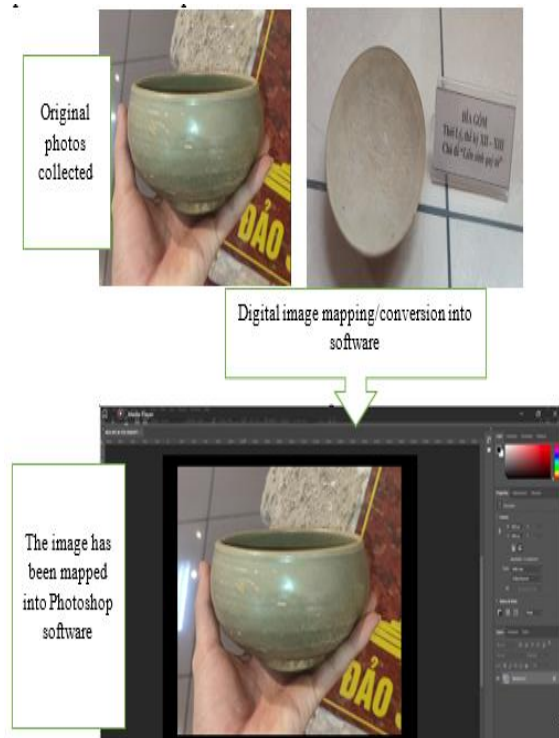


Fig. 3: 3The process of mapping artefact images

Source: created by the authors

Next, we need to process the noise and adjust the captured image.



Fig. 4: 4Image noise processing

Source: created by the authors

The figure 4 above illustrates the process of noise reduction and image adjustment to ensure the best possible image quality. After the images of each artefact have been captured and converted/mapped into graphic software, noise reduction, adjustment, and fine-tuning are performed to ensure image quality, size, etc.

After the images have been processed to remove noise and ensure quality, it is necessary to apply techniques to overlay textures/materials onto the surfaces of the 3D models (See details in Figure 5).

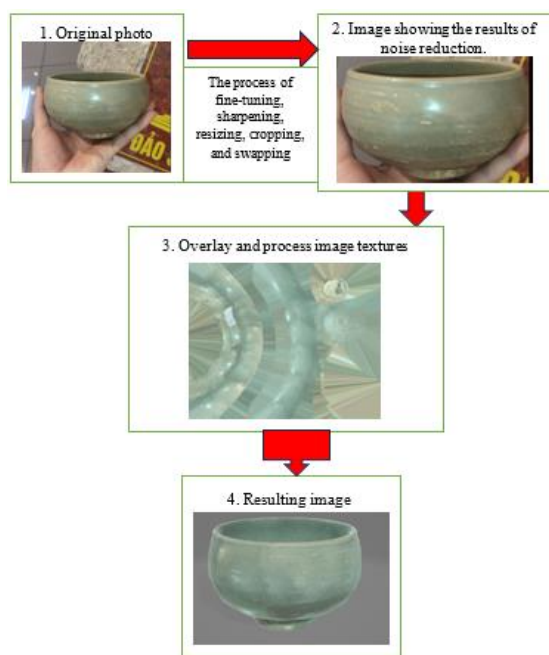


Fig. 5: 5Overlay and process image textures

Source: created by the authors

Above is the result of an image of an artefact, a bowl, created by applying a texture to its surface.

Thus, based on the catalogue of historical and cultural artefacts and documents currently stored, preserved, and promoted at the Tuyen Quang Provincial Museum, the research team conducted surveys, collected data, processed graphics, and as a result, digitised 150 artefacts (See details in Figure 6):

Developed a website providing information on the artifacts, which has been installed at the Tuyen Quang Provincial Museum in Vietnam [15]:

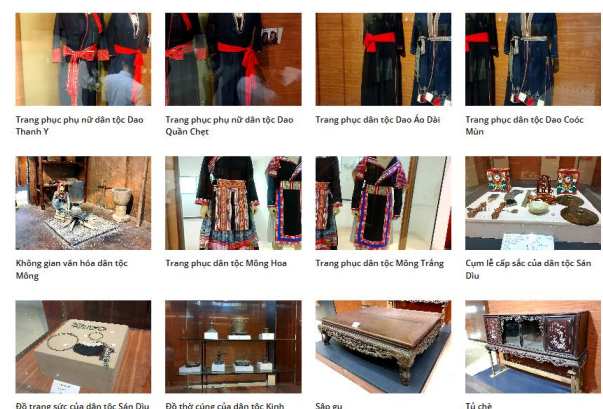
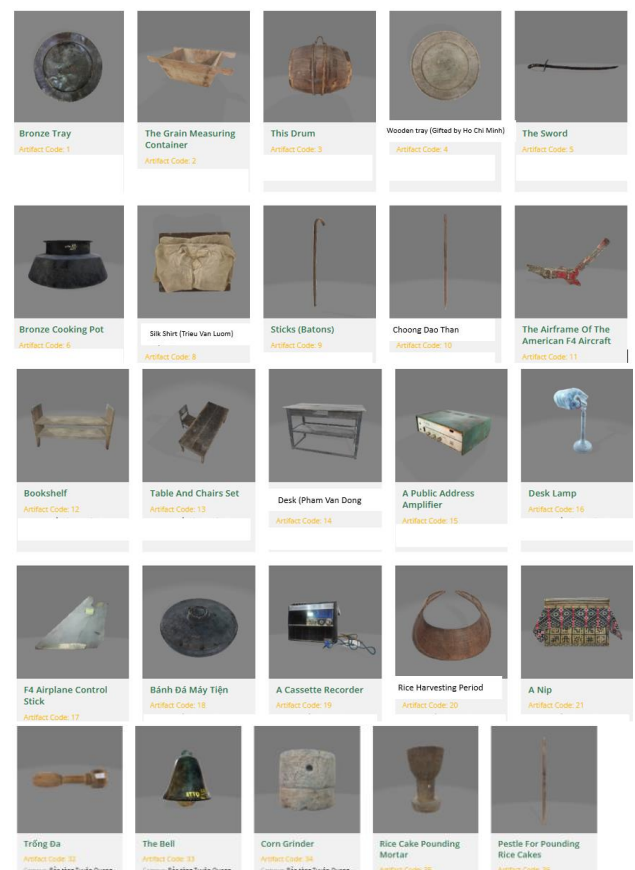


Fig. 6: 6The list of digitised artefacts has been integrated into the web system

Source: created by the authors

The results show that digitisation and QR code labelling have been implemented to facilitate interaction and information retrieval for tourists and locals regarding artefacts:

Since the beginning of 2025, the initiative's creator has collected image data from approximately 150 artefacts, along with standardising the information for each artefact. The initiative has successfully digitised 150 artefacts. The artefacts were digitised using cameras and scanners to copy images of each artefact.

These images were then processed using graphic design software such as 3Ds Max, noise reduction was performed, and complete models were constructed.

Finally, the initiative integrated the data onto a website and created QR codes for each artefact on the website of the Tuyen Quang Provincial Museum, Vietnam [15]. The QR codes have been affixed to the display cases of the artefacts and are available for visitors and locals to scan to view and search for information and images of each artefact, along with automatic explanations.

5 Evaluating the implementation solution

5.1 Evaluation of the implementation of the digital transformation solution and the construction of a system for searching information on artefacts

- Accuracy and completeness of information displayed via QR code

Information on artefacts accessed via QR code must be accurate, clear, and complete with all components: artefact name, origin, age, material, image/3D, historical and cultural value, and multimedia explanation.

- Stable and user-friendly access: The search system must ensure fast QR scanning, ease of use on multiple smart devices, a user-friendly interface, fast loading speed, and no need to install complex additional applications.

- Integration with digital technology and 3D models: QR codes should not only provide text and image content, but can also integrate explanatory videos, 3D models, and even support augmented reality (AR/VR) interactive experiences.

- The QR code-based search system's ability to support education, exhibition, and cultural promotion must contribute to improving the quality of visits, assisting students, researchers, and others in quickly accessing information, and making the museum more vibrant and attractive.

- The system's flexibility, security, and scalability must allow for easy updating of artefacts, support multiple languages, manage access effectively, ensure data security, and be expandable into an online search system or digital museum.

Benefits of the Implementation Solution

- Economic Benefits:

Optimising costs for traditional explanatory materials, printing, and design of explanatory boards.

Reducing preservation costs by minimising direct contact with physical artefacts.

Creating conditions for the development of digital tourism products, online museums, and smart experiential tours, contributing to increased revenue from museum services and cultural tourism.

The model can be replicated for other historical sites and museums in the province.

- Educational and Research Benefits

Effectively supports students, researchers, and others in quickly, fully, accurately, and visually accessing information about artefacts.

3D artifact modeling and digital data make teaching history and culture more engaging and understandable, sparking interest in learning.

Provides a long-term source of digitised materials for scientific research, archiving, and exploiting cultural heritage.

Contributes to the dissemination of local historical and cultural knowledge through digital learning and media platforms.

- Social and Cultural Benefits

Promotes the value of Tuyen Quang province's cultural heritage, widely publicising the image of the homeland, the "Capital of the Liberation Zone - Capital of the Resistance," domestically and internationally.

Increases accessibility for the community, especially young people, international visitors, people with disabilities, and online visitors.

Contributes to sustainable heritage preservation, aligning with the digital transformation strategy of the culture, tourism, and education sectors. Promoting the formation of "Smart Museums," in line with the trend of digital transformation and experiential tourism in the 4.0 era.

6 Conclusion

The digital transformation solution and the development of a QR code-based artefact information retrieval system at the Tuyen Quang Provincial Museum help to digitise, store, and manage artefacts effectively, while enhancing the visitor experience, educa-

tion, and promotion of local culture. The QR code system, combined with 3D models, digital explanations, and scientific data, facilitates quick retrieval, intuitive interaction, cost savings, and expanded accessibility for both domestic and international audiences. This solution contributes to the sustainable preservation of heritage and the development of smart museums and aligns with the digital transformation direction of the culture and tourism sector.

The creation and digitisation of 3D artefact models play a vital role in the development of virtual reality applications, as these models serve as the fundamental elements for constructing immersive virtual environments. This study examines several techniques for generating 3D models of artefacts preserved at the Tuyen Quang Provincial Museum. It also describes the workflow for 3D reconstruction and presents methods for applying textures to enhance the visual realism of the resulting artefact models.

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Conflict of Interest.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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