

Digital Mapping and Public Dissemination of Cultural Heritage: A Case Study of “Chengzhitang in Huizhou”

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Abstract:

The value of digital technology in the preservation and utilization of cultural heritage far exceeds simple data storage functions. Its deeper significance lies in the ability to recreate historical scenes, widely disseminate profound cultural heritage, and exert a profound impact on modern society. Taking the architecture and decoration of Chengzhitang in Huizhou as an example, this paper delves into how to leverage digital technology to create immersive experiences in the preservation, exhibition, and cultural transmission of cultural heritage. It focuses on how to accurately and comprehensively present the cultural heritage itself and its underlying historical and cultural background, how to maximize the use of the outcomes of digital preservation technology, and how to facilitate deep-level interaction between culture and audiences, thereby promoting sustainable development based on new digital cultural heritage.

Keywords:

Cultural Heritage, Digital Surveying and Mapping, Public Dissemination

1. Introduction

The protection of cultural heritage has become a hot topic of global consensus, with its core mission being the adoption of diverse strategies to maintain the tangible and intangible heritage of human society, defend cultural diversity, and ensure the intergenerational transmission of historical, artistic, and scientific value. However, current technical means, while able to slow natural erosion in physical restoration and protection, are limited in effectiveness by uncertainties, and occasional protective damage still poses a challenge. Beyond direct protective measures, it is equally important how to reinterpret, promote, and develop the value of cultural heritage in the contemporary context. Digital technology, with its characteristics of easy storage, convenient replication, and high editability, demonstrates significant advantages in the archiving, in-depth research, and broad transmission of cultural heritage information, becoming a core means of promoting the long-term preservation and value enhancement of cultural heritage.

Initially, digital tools were mainly used for the collection, registration, and archiving of cultural heritage and its information, such as building comprehensive data warehouses or management systems. Taking the European digital library Europeana as an example, since its launch in 2008, thanks to the strong support of multiple European countries and thousands of institutions, it has successfully transformed iconic European cultural heritage resources into digital form, opening a window for the public to access rich cultural resources and setting a benchmark for the digital protection of cultural heritage. [1] The value of digital technology in the field of cultural heritage extends far beyond digital archiving; it lies more in its ability to recreate historical scenes, promote cultural exchange, and exert a profound impact on modern society. The practice of digital surveying and mapping and dissemination discussed in this article aims to use digital technology in the processes of cultural heritage protection, exhibition, and dissemination to design and implement digital content presentation and intelligent service solutions for the public. The key lies in how to create new forms of digital assets for cultural heritage, craft unique experiences through digital technology, and fully demonstrate the cultural connotations of cultural heritage in contemporary society. This is the core challenge and mission faced by the design field when intervening in cultural heritage protection.[2]

2. Immersive Interactive System Architecture for Chengzhi Hall Architecture and Carving Art

The architecture of the immersive interactive system for Chengzhi Hall's architectural space and carving art (referred to as the "Touch Chengzhi Hall" project in this paper), progresses through information collection, material research and virtual scene design, virtual scene production, to final presentation. It aims to reproduce the splendor of ancient Huizhou architecture and the essence of carving art, inherit the profound heritage of Chinese culture, create an immersive experience for visitors, stimulate strong emotional resonance and participation, tell the Huizhou story in innovative ways, and allow the public to awaken cultural memory and revitalize cultural vitality through personal experience. (Figure 1)

The virtual interactive show is carefully divided into two main sections: the Immersive Interactive Experience Zone and the Contextual Exploration Zone. In the Immersive Interactive Zone, a virtual world is woven together by a giant wrap-around screen and interactive floor projections. Every step triggers floor interactions, vividly showcasing the delicate architectural carving style of Chengzhi Hall. Through cutting-edge digital scanning, virtual reconstruction, color restoration, and historical document tracing technologies, one can deeply understand the regeneration path of Huizhou architecture under the power of science. As the virtual environment gradually completes, the architectural carving art of Chengzhi Hall reappears before the eyes. The Contextual Exploration Zone uses key digital restoration scenes as guides, integrating cultural knowledge, live recordings of the restoration site, and diverse interactive experiences to reveal the digital origins of Chengzhi Hall's carving art. Visitors can personally experience models of architectural surveying tools, participate in interactive color restoration games, and explore every corner of Chengzhi Hall in a virtual reality environment. To measure the effectiveness of the experience, we set up a pre-and-post comparison interactive session. The data collected before and after the interaction provides valuable insights: how to reshape public perception of cultural heritage within a limited time, establish a deep emotional

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graph TD
    subgraph Information_Integration [Information Integration]
        IF[Information Feedback]
        CHCL[Cultural Heritage Component Library]
        CHC[Cultural Heritage Collection]
        HDC[Historical Data Collection]
        RSC[Research Records of Similar Cases]
    end

    subgraph Data_Research_Virtual_Scene_Design [Data Research & Virtual Scene Design]
        VAS[Virtual Assembly / Splicing]
        DIS[Data Integration and Screening]
        SRR[Scene Restoration Research]
        DED[Design Drawing / Drafting]
        CHSS[Chengzhi Hall Specific Standards / Specifications]
        AM[Assisted Refinement]
        TML[Texture Material Library]
    end

    subgraph Virtual_Scene_Production [Virtual Scene Production]
        3DM[3D Modeling]
        MTM[Material Texturing / Texture Mapping]
        SI[Scene Integration]
        ACL[Architectural Carving Component Library]
        ASML[Architectural Space Material Library]
    end

    subgraph Result_Presentation [Result Presentation]
        VTS[Virtual Tour System]
        EI[Exhibition Introduction]
        PD[Product Development]
        TGP[The Public / General Public]
    end

    IF --> CHCL
    CHCL --> VAS
    CHC --> DIS
    HDC --> DIS
    RSC --> DIS
    RSC --> SRR
    RSC --> TML
    DIS --> SRR
    SRR --> DED
    SRR --> CHSS
    SRR --> TML
    DED --> AM
    AM --> DIS
    AM --> 3DM
    CHSS --> 3DM
    3DM --> MTM
    MTM --> SI
    MTM --> ASML
    SI --> VTS
    SI --> EI
    SI --> PD
    VTS --> TGP
    EI --> TGP
    PD --> TGP
    TGP --> IF
    IF --> IF
  
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The flowchart illustrates the research framework for the virtual restoration of the Chengzhi Hall, organized into four main stages:

- Information Integration:** This stage involves gathering initial data from sources like the Cultural Heritage Component Library, Cultural Heritage Collection, Historical Data Collection, and Research Records of Similar Cases. It also includes an Information Feedback loop.
- Data Research & Virtual Scene Design:** This stage focuses on processing the data through Virtual Assembly / Splicing, Data Integration and Screening, and Scene Restoration Research. It also involves Design Drawing / Drafting, Chengzhi Hall Specific Standards / Specifications, and the Texture Material Library. An Assisted Refinement loop connects Design Drawing / Drafting back to Data Integration and Screening.
- Virtual Scene Production:** This stage involves 3D Modeling, Material Texturing / Texture Mapping, and Scene Integration. It also utilizes the Architectural Carving Component Library and the Architectural Space Material Library.
- Result Presentation:** The final stage involves the Virtual Tour System, Exhibition Introduction, and Product Development, all leading to The Public / General Public. A feedback loop from The Public / General Public returns to the Information Feedback stage.

Continuous Maintenance, Supplementation, Update

3. Digital Technology Solutions

For a long time in the field of digital preservation for cultural relics and museums, laser scanning technology has been widely used due to its efficient data acquisition capabilities, excellent accuracy, and non-contact characteristics. Taking the digitalization team of Zhejiang University's Cultural Heritage Institute as an example, they used the FARO ScanArm high-precision scanning arm and FARO Focus large-space laser scanner, successfully overcoming various scanning difficulties encountered in multiple projects and setting an industry standard for high-precision digital archiving of cultural relics.[4] These valuable experiences are of significant reference value for the digital surveying and mapping work of Huizhou Chengzhi Hall. Although laser scanning technology is precise and efficient, its massive data output also brings inconvenience in editing and dissemination. Coupled with high costs and environmental sensitivity, and the potential damage to artifacts in extreme cases, this technology faces certain limitations in practical application.

In recent years, an emerging photogrammetry technology has shown significant advantages compared to traditional digitalization methods. Photogrammetry technology, based on sequential images, achieves 3D model construction through a series of steps including image preprocessing, camera calibration (i.e., using image data to infer the position of spatial objects), and point cloud triangulation (a core part of the 3D reconstruction process). Behind this technology lies an integration of knowledge systems from multiple disciplines such as image processing, computer graphics, visual processing, geometric modeling, and mathematical algorithms. Users only need to use ordinary cameras or smartphones to capture a series of digital photos of the target object. These photos can then be uploaded and automatically integrated into detailed 3D digital models, constructing realistic virtual environments. Models generated by photogrammetry are not only lightweight in data volume, facilitating subsequent editing and sharing, but are also widely compatible with various industry-standard formats (such as 3DS, OBJ, STL, WRL, etc.), making model processing more flexible and diverse. With the assistance of AIGC, the entire project becomes more intelligent.

Currently available photogrammetry software on the market, such as 3DCloud, SketchUp, Image Modeler, and the Autodesk 123D series software suite launched by Autodesk, provide users with diverse 3D modeling approaches. Among them, 123D Catch, as a cloud-based photogrammetry solution, can quickly convert digital photos into 3D models and supports cloud processing and convenient model editing functions. Its simple operation, low cost, and high efficiency make it a model of 3D photography technology, widely applicable for large-scale promotion and network sharing. The ENEA research center of the Italian UTICT agency has successfully used 123D Catch technology to digitally restore iconic locations such as Rome's Capitoline Square, Piazza Navona, and Bologna's Piazza Maggiore, vividly reproducing the sculptural art treasures in these squares. [4] The architectural carvings of Huizhou Chengzhi Hall can achieve efficient digital protection and virtual display through this photogrammetry technology path, opening new avenues for cultural heritage preservation.

4. Digital Surveying and Mapping Collection

In the digital surveying, mapping, and data collection work for Huizhou Chengzhi Hall, to ensure the high quality of surveying and collected data, and to meet the requirements of modeling software like 123D Catch, we systematically conducted multi-angle shooting around Huizhou Chengzhi Hall on circular paths with reasonably spaced intervals, comprehensively covering the front, back, left, and right four directions. During implementation, we adopted a strategy of seamless 360-degree shooting around key parts of Chengzhi Hall, for example, rotating horizontally by 20 degrees each time, ensuring about 18 photos were taken in one circle, thereby constructing detailed 3D image data. Given the characteristics of Chengzhi Hall as a static architectural object and its unique building materials and style, this 3D image acquisition strategy based on a panoramic perspective is particularly appropriate and efficient. [5]

During the data collection phase, we ensured that appropriate visual overlap was maintained between every two adjacent photos, providing a crucial basis for subsequent processing. By analyzing the correlations between images in these overlapping areas, we could accurately calculate the optical properties of the camera and the transformation rules of the spatial coordinate system. Using advanced

computer vision algorithms for precise matching of image feature points, we determined the exact position of the object in 3D space. This process was transformed into a 3D model through mesh refinement and texture mapping techniques, ensuring the model's fineness and realism. [6] With the help of professional computer graphics methods, we not only successfully constructed a highly accurate digital 3D representation of Huizhou Chengzhi Hall but also meticulously recorded every detail of its surface patterns and textures. These valuable visual materials possess both broad potential for practical application and significant importance for academic research.

The digital virtual restoration work for Huizhou Chengzhi Hall, on one hand, involves using digital means for fine virtual repairs of damaged or incomplete parts of the existing building, striving to restore its original appearance. On the other hand, for lost architectural elements, we employ virtual reconstruction technology to give them new life in the digital world, allowing the entire architectural complex to be fully represented in virtual space. Addressing the current state of Huizhou Chengzhi Hall, erosion over the years has intensified weathering and damage, with some parts of the building showing signs of decay. Traditional physical restoration methods, such as adhesive repairs, are limited by technical levels and may inadvertently cause secondary damage to Chengzhi Hall. Many architectural details have unfortunately suffered “protective damage” during restoration, and these rigid repairs are often difficult to adjust or remedy later. Virtual restoration using photogrammetry avoids direct contact with the physical building. Relying on intelligent recognition of fracture surfaces, fine feature extraction, and precise matching technology between fragments, it performs high-precision restoration work on Chengzhi Hall within the digital domain. Simply by using the 3D data of Chengzhi Hall, computer simulation modeling can perfectly recreate missing parts in virtual space, achieving visual effects indistinguishable from the real object.

The ideal Huizhou Chengzhi Hall architecture and carving art are composed of diverse parts, each carving component carrying the unique historical and cultural heritage of Huizhou. Through digital virtual restoration, relying on high-precision 3D scanning technology, physical replication of Chengzhi Hall's architectural elements is achieved, reproducing the building and its carving art. Simultaneously, for damaged or missing parts of the existing building, repair molds can be accurately generated, feeding back into the physical building's restoration work, ensuring the repair effect perfectly matches and integrates with the original cross-section.

5. Immersive Interactive System Construction

Based on detailed data surveying and collection work, the “Touch Chengzhi Hall” project was meticulously planned across three dimensions: spatial layout, content curation, and experience design, offering a unique interpretation of relevance, immersion depth, personal experience, and interactivity in cultural heritage communication. Simultaneously, the project skillfully integrated modular design thinking and hardware-software integration strategies at the practical level, endowing “Touch Chengzhi Hall” with high replicability, promotional power, and potential for touring exhibitions.

In creating the spatial atmosphere, the “Touch Chengzhi Hall” project paid particular attention to fostering spatial immersion and subtly guiding audience emotions. The entire exhibition space revolves around the wrap-around screen immersive hall. As visitors step into the hall, they are immediately drawn to the

vividly recreated century-old appearance of Huizhou Chengzhi Hall on the screen. Guided by narrative text, visitors gradually form a mental picture of the entire Chengzhi Hall building and its carving artworks. The design, free of physical barriers, allows visitors to move freely and deeply engage with the exhibition content. Interactive images constructed using high-definition laser projection technology, alternating between concrete scenes and abstract elements, create a visual feast that is both real and dreamlike: sometimes precisely replicating the original appearance of Chengzhi Hall through omnidirectional camera captures, giving visitors a strong sense of presence; other times using rich visual information to blur spatial boundaries, leading visitors on a fantastical visual journey. In the subtle interplay between the virtual and the real, the audience's sensory experience and emotional resonance are deeply stimulated.

At the content conception level, "Touch Chengzhi Hall" strives to build a profound personal experience. For instance, when explaining existing architectural components of Chengzhi Hall, the project not only details their materials and names but also delves deeper, based on academic research, to reveal the original uses of these components and the cultural significance of the architectural carving art they embody. This narrative method, although using static text as a medium, vividly presents a flowing historical context, enabling the audience to travel through time and perceive the historical changes of the building. Furthermore, in the virtual component assembly segment, the team uses realistic techniques and a rigorous narrative structure to delicately recreate the assembly process, making the audience feel as if they are personally present, working alongside researchers, thus striking a chord and achieving strong emotional resonance.

"Touch Chengzhi Hall" emphasizes participation and interaction, aiming to break down barriers between content and audience, promoting active interaction and connection. As visitors enter the immersive interactive space and explore freely, their movements trigger radar sensors, progressively revealing the architectural carving art details of Chengzhi Hall along their path, ultimately unveiling the complete view of Chengzhi Hall surrounding them. Additionally, pre- and post-exhibition voting sessions enhance participation, allowing visitors to share their unique insights and feelings about Chengzhi Hall. This not only deepens personal memory but also activates the interactive atmosphere of the exhibition. Voting becomes a bridge connecting audience emotions, stimulating more discussion and sharing. Excellent public communication strategies for cultural heritage hinge on sparking public interest in discussion and creating opportunities for social interaction. Furthermore, scenario-recreation exhibition areas are also effective means of creating topics and social atmosphere. Within the immersive interactive space, although visitors are keen to take photos and share them online, direct communication among co-visitors is relatively limited. However, upon entering the scenario exhibition area, visitors can deepen their understanding of the exhibition content through detailed study of documents and physical interaction like touching replicas of artifacts. This deep engagement encourages them to stay longer in the area, engaging in lively discussions around shared points of interest.

Regarding implementation strategy, the "Touch Chengzhi Hall" immersive interactive exhibition adopts a highly modular design concept, emphasizing standardization, reusability, and flexibility. From hardware equipment configuration, exhibition venue layout, to the planning of the overall operational model, standardized modular construction ensures both the adaptability of the exhibition space and the

diversity of content delivery. On the other hand, the modular design ensures adaptability to different display spaces and the capacity to meet diverse needs, thus laying a solid foundation for the widespread replication and recombination application of “Touch Chengzhi Hall”. Simultaneously, at the digital content level, the exhibition design also fully considers future technological updates and the richness of presentation forms. During promotion, audience feedback is continuously used to adjust exhibition content and presentation forms, maintaining content vitality and visual appeal.

6. Conclusions

The digital interpretation of cultural heritage opens up diverse and flexible pathways for its presentation, greatly broadening the dimensions and depth of cultural explanation, transcending the limitations of time and space, and attracting the attention of a wider public audience. On the communication bridge facing the public, as “narrators” of history, we must adhere to design thinking, closely follow the pulse of user needs, and implement comprehensive measures from content arrangement, user experience optimization, to spatial layout innovation. The aim is to create an experience of deep emotional connection, immersive exploration, personal realization, and interactive participation, promoting deep-level exchange with the public in terms of emotional resonance, knowledge transfer, and behavioral interaction. The core of this series of efforts lies in accurately grasping the core value of the cultural heritage and carefully selecting content elements that can highlight these values. Subsequently, centering on this core, creative experience design, spatial conception, and interaction strategies are developed, ensuring that every design step closely serves the communication of the core value.

By applying the most suitable technological means, the design vision can be maximized. Digital cultural heritage products that integrate content essence, creative inspiration, and cutting-edge technology can profoundly touch the audience’s hearts, build cultural bonds, and become a public sphere for communication and exchange. Cultural heritage can achieve truly living inheritance. In summary, digital preservation serves as a key strategy for cultural heritage protection. Through advanced technology and design concepts, we are able to conduct comprehensive, precise digital recording and vivid presentation of valuable heritage like Huizhou Chengzhi Hall, paving a solid path for its future long-term preservation and widespread dissemination.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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