https://doi.org/10.37420/j.adr.2024.012

The digital preservation of national memorial architecture: A new approach with BIM and VR technology

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Abstract:

National memorial architecture serves as a testament to civilization, embodying and perpetuating a nation's culture, values, and identity. It facilitates the preservation of historical events or memories for future generations to reference while symbolising national pride and unity. However, the conservation of such monuments currently faces numerous challenges, including the impact of unforeseeable forces, excessive tourism, and inadequate funding. In response to these challenges, this paper proposes a solution utilizing Building Information Modeling (BIM) and Virtual Reality (VR) technologies for digital preservation. BIM enables comprehensive data collection of commemorative structures, while VR provides immersive virtual experiences, enhancing public understanding and engagement with these monuments. Using the People's Heroes Memorial Tower in Zhangcun, Siming Mountain Martyrs Cemetery, Ningbo, Zhejiang, China, as a case study, this paper demonstrates the entire process of digital preservation and explores the potential applications of these technologies in safeguarding national memorial architecture.

Keywords:

National memorial architecture conservation, Building Information Modeling, Virtual Reality, Architectural digital technology

1.Introduction

1.1 Monumental Architecture

Monumental architecture comprises distinct buildings or structures erected to commemorate historical events, heroes, or other significant symbols of a nation. These edifices are often crafted to uphold the memory of influential figures, pivotal occurrences, or foundational principles that have molded national identity and history [1]. Depending on the nature of the memorialized subject, monumental architecture can be categorized as follows: 1) Historical Figures Memorial Architecture: These structures honor noteworthy figures from history, such as the Washington Monument, Lincoln Memorial, and Piazzale Michelangelo. 2) Group or Organization Memorial Buildings: Erected to commemorate a collective, organization, or institution—be it military, educational, or charitable, including the U.S. Marine Corps War Memorial and the Monument to the People's Heroes. 3) Event Memorial Buildings: Designed to memorialize significant historical events, wars, revolutions, disasters, etc. Notable examples include the Pearl Harbor National Memorial and the Monument to the People's Liberation.

1.1.1 Importance of National Memorial Architecture

Monumental architecture serves not only as a significant symbol of a country but also as a vital platform for cultural preservation, historical education, national unity, and tourism development, exerting a profound influence on the nation's progress and societal evolution.

These structures stand as emblematic representations of a country, encapsulating its distinctive culture, values, and national ethos. They embody a nation's historical legacy, patriotic fervor, and cultural resilience, often embodying collective memories and shared consciousness while symbolizing unity. Monumental architecture has the power to galvanize national spirit, fortify societal cohesion, and foster social harmony and stability.

As witnesses to history, monumental architectures carry the weight of past events and the valor of heroes and heroines, transmitting their significance to future generations. They serve as conduits for historical transmission, cultural dissemination, and a reminder to cherish the lessons of history. These commemorative edifices not only preserve history but also serve as educational resources, playing a pivotal role in public historical consciousness. They instill reverence for history, bolster national pride, and reinforce a sense of national identity.

Moreover, many monumental architectures have evolved into significant tourist destinations, drawing crowds of visitors. These sites play a constructive role in stimulating local economic growth and employment opportunities. Additionally, national monumental architectures offer foreign tourists a gateway to understand a country's history and culture, facilitating cross-cultural exchange and fostering mutual understanding.

1.1.2 Status of Conservation of Monumental Architectures

Currently, many countries have established specialized agencies or departments responsible for the management and preservation of monumental architecture. Examples include the National Park Service (NPS) in the United States, the Canberra National Memorials Committee in Australia, and the Ministry for Culture and Heritage in New Zealand. For instance, under the auspices of such agencies, the Washington Monument underwent maintenance twice, in 2011 and 2016, while the Eiffel Tower has been repainted several times to prevent corrosion.

Governments worldwide have also enacted laws and regulations to safeguard monumental architecture, typically imposing strict prohibitions against vandalism, theft, or damage. These legal frameworks provide legal safeguards for specialized agencies or departments and play a crucial role in maintaining the integrity of monumental architecture. In the United States, the National Historic Preservation Act was enacted in 1966 to protect the nation's historic sites and cultural heritage resources, including monumental architecture. Pennsylvania law stipulates that an individual is guilty of a second-degree misdemeanor if they intentionally desecrate any public monumental building, structure, place of worship, or cemetery.

Monumental architecture in some countries has garnered attention and support from international organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Committee. Through international cooperation and exchange, countries can draw upon the experiences and techniques of others, including the exchange of conservation and restoration techniques, management experiences, display and educational methods, thereby collectively advancing the protection and transmission of cultural heritage.

However, monumental architecture faces several challenges:

Impact of Force Majeure: Natural disasters like earthquakes, storms, and conflicts can cause substantial damage or destruction to monumental buildings, including structural cracks and collapses, posing significant and often unavoidable conservation challenges. Additionally, inadequate disaster preparedness, response plans, and restoration efforts exacerbate these challenges.

Excessive Visitors: Some monumental buildings attract large numbers of visitors annually due to their prominence or historical significance. High visitor volumes can strain the structural integrity of these buildings and complicate maintenance and management efforts. Tourist behaviors such as touching, graffiti, and climbing can damage surface carvings or building materials, compromising the original condition of the structure. Furthermore, tourism influx may harm the surrounding natural environment [2].

Limited Funding: Insufficient funding presents a significant obstacle to the preservation of monumental buildings. Substantial financial resources are required for disaster prevention, repairs, and maintenance. However, constrained budgets may impede necessary conservation efforts, thereby jeopardizing these structures' historical and cultural value [3].

1.2 Digital protection

BIM (Building Information Modeling) is a technology rooted in digital information modeling, while VR (Virtual Reality) offers immersive virtual experiences. By integrating these two technologies in the digitization of monumental architecture, it becomes possible to achieve both digital preservation and immersive visual simulation experiences.

1.2.1 BIM Technology

BIM plays a role as a digital driver in building design, construction, and management. The digital 3D models will be utilized throughout the entire lifecycle of a building project. In digitization projects focused on monumental architecture, BIM is instrumental in preserving a wide array of information pertaining to these structures.

Through BIM technology, monumental architecture is authentically recreated within a virtual environment, facilitating the establishment of a comprehensive 3D digital model. This model encompasses not only basic information like geographical location, architectural composition, and surrounding environment but also intricate details such as building facades and internal layouts [4]. Utilizing BIM ensures the high precision and comprehensive digitization of monumental architecture.

Point cloud data serves as one of the primary sources for generating 3D digital models. In photogrammetry, multiple viewpoints of an object are captured using a camera, and computer vision algorithms reconstruct a 3D model based on feature points and spatial location information extracted from the images. This process essentially involves reverse modeling based on the physical structure of the building [5].

1.2.2 VR technology

VR is a revolutionary interactive environment simulated through computer technology, enabling users to immerse themselves in a virtual three-dimensional world. Users can observe, move, and interact with the virtual environment using devices like head-mounted displays, thus achieving immersive experiences [6].

With VR devices such as Oculus Quest 2 and Apple Vision Pro, users can virtually tour monumental architecture, observing its authentic exterior and internal structure, and experiencing historical scenes and cultural ambiance. This immersive experience greatly enhances users' understanding and appreciation of monumental architecture. Creating simulation browsing modes that combine virtual and real elements breaks the limitations of time and space.

2. Digital protection process

The digital conservation of monumental buildings is mainly divided into three steps: information collection, BIM 3D model production, and VR scene production. This study will take the memorial tower of Simeingshan Martyrs' Cemetery as an example of the whole digital conservation process of monumental buildings.

Located in Zhangcun, Zhangshui Town, Yinzhou District, Ningbo City, Zhejiang Province, the Siming Mountain Martyrs' Mausoleum was built in December 1944 to commemorate the revolutionary martyrs who died bravely in battle. This mausoleum was built on the joint initiative of the New Fourth Army East Zhejiang Guerrilla Column, the Siming Special Office and the Yinfeng County Office. It includes buildings such as a memorial tower, a martyrs' memorial hall, an outdoor weapons display, a group sculpture, and a martyrs' graveyard. In the centre of the mausoleum is a 44.12-metre-high marble memorial tower standing in the square, symbolizing the eternal remembrance of the martyrs.

2.1 Information collection

2.1.1 Field data collection

Before collecting data from the experimental area, planning should be done in advance according to the specific operational tasks. Planning includes selecting a suitable experimental area and making a flight plan for aerial photography. We chose DJI Phantom 4 RTK for aerial photography this time (shown in Fig. 1), which was used by A Pellegrinelli for photogrammetric modelling of the building [7].

Figure 1. Aerial photography

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https://doi.org/10.37420/j.adr.2024.012

Zhangcun Simeingshan Martyrs' Cemetery is a no-fly zone, and the aerial photography permit was obtained after reporting and approval by the relevant departments. The rear is close to the rocky mountain and the height of this aerial photograph is set at 100m, according to the requirement of the overlapping degree of the photograph in the relevant specification of low altitude digital aerial photography, the overlapping degree of heading should be kept at 60%-80%, but not less than 53%; the overlapping degree of side direction should be kept at 15%-60%, but not less than 80%.As this operation is a 3D tilt photography, a five-lens camera is mounted on the same UAV to collect image data from multiple angles, such as vertical and tilt, to obtain complete and accurate texture data and positioning information. The camera tilt angle is between 40° and 60°, so that the contour and texture information of the side of the feature can be obtained in a more complete way. The final data is used for modelling, and a repetition rate of 80% is required, so five-way flights are used to obtain the corresponding aerial data (as shown in Figure 2). Manual measurements were taken to complete the data in areas that were difficult for the UAV to photograph (shown in Figure 3).

Figure2. Aerial photograph

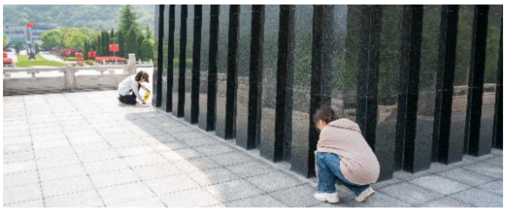

Figure3. Manual measurement of photographs

2.1.2 Tilt-shot modelling

The aerial modelling data collected by the UAV will be imported into ContextCapture to check whether the image is qualified, delete unqualified images such as reflective water surfaces, etc., and check that there is no error for the aerotriangulation of digital aerophotogrammetry (shown in Figs. 4 and 5), where AT refers to the use of the spatial geometrical relationship between the image and the target to be captured in photogrammetry. The process of calculating the camera position attitude and the sparse point cloud of the target captured at the moment of camera imaging from the correspondence between the image points and the object captured. After AT processing, it can quickly determine whether the quality of the raw data meets the project delivery requirements and whether images need to be added or deleted. Both two-dimensional reconstruction and three-dimensional reconstruction must first do air three processing, air three computing is completed to confirm that the aerial survey data has reached the standard required by this task, to carry out the selection of the modelling area, to determine the number of tiles, and to carry out the three-dimensional reconstruction of the inclined photographic model (shown in Figs. 6 and 7). Finally, water surface holes were patched and tree debris removed to refine the model at Super Map.

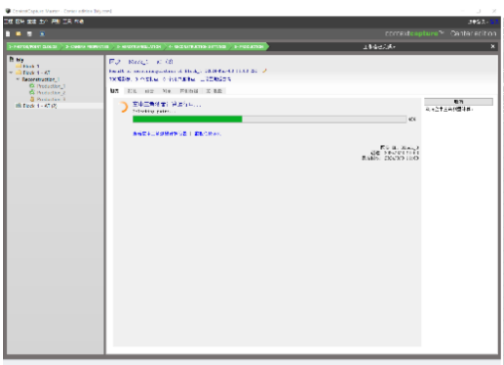

Figure4.AT data processing

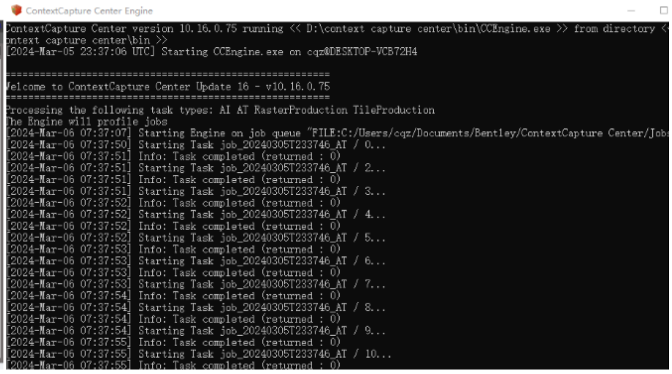

Figure5.Related engines

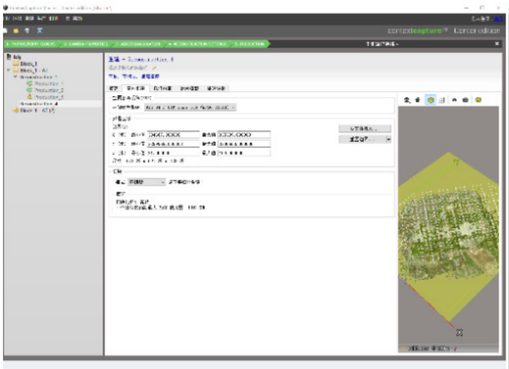

Figure6. 3D model reconstruction

Figure7. Inclined photographic model

2.2 BIM 3D modelling

According to the relevant 2D plan, elevation, section drawings, tilt camera model, manual mapping data with Revit software for civil, structural, piping and other professional modelling (as shown in Figure 8), for the relevant doors, windows, supports and other components of the family model building, to complete the update of the Revit Families library (as shown in Figure 9). And carry out relevant collision tests to check whether there are any problems in the model [8].

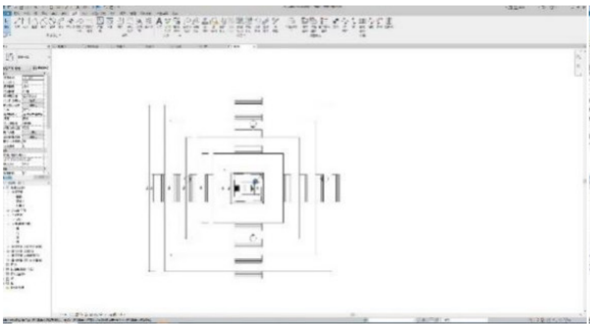

Figure8. Modelling process

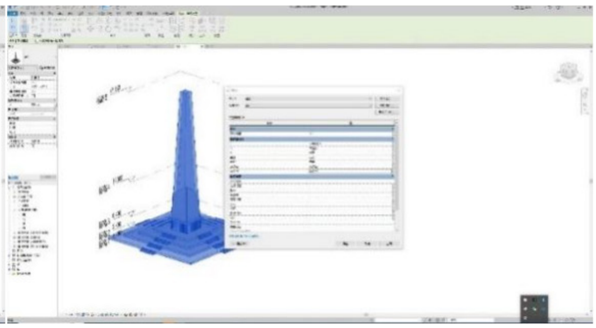

Figure9. Modelling data

2.3 VR Scene Production

2.3.1 Loading local model resources

https://doi.org/10.37420/j.adr.2024.012

Rendering BIM models into panoramic views for presentation in VR can offer users immersive experiences, leading to the development of a novel promotional approach.

Inclined photographic models are usually data-heavy, and it is important to achieve smooth loading of the scene. We use Cesium to convert the osgb, obj and other formats of the tilt camera model into the standard 3D Tileset format (Figure 10), add Cesium 3D Tiles to the Cesium of Unreal plugin for the Unreal Engine 5 [9], change the Source to "From URL" to fill in the path of the file, and then efficiently load the live model in Unreal Engine 5 (Figure 11).

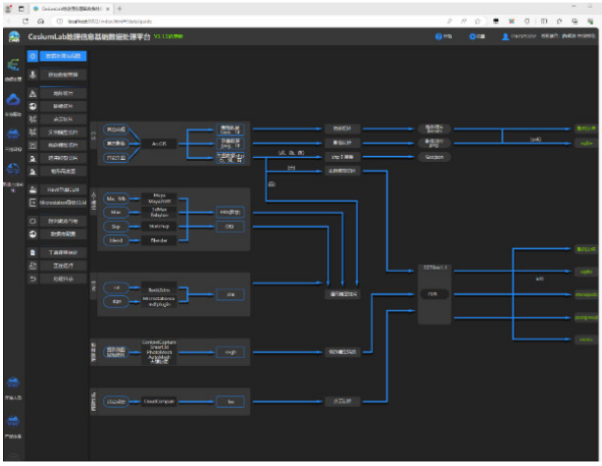

Figure10.Cesium Interface

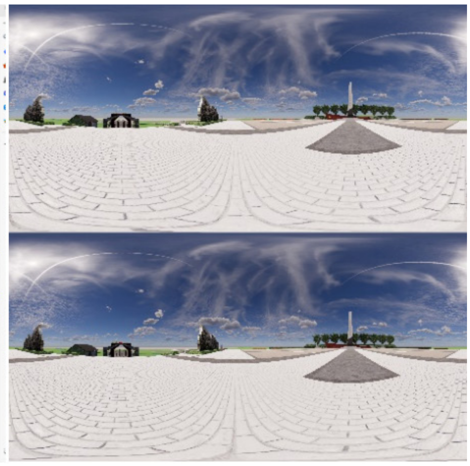

Figure11. 3D Panorama

2.3.2 Loading Cesium's geoenvironmental resource-filled scenarios

The Cesium Geore ference Blueprint Object Details panel enters the appropriate longitude, latitude, and altitude values to accurately position the live model on the earth, and adds the Cesium World Terrain + Bing Maps Aerial imagery system to Cesium's Quick ADD to automatically The system will automatically populate the Earth background in the nearby areas. Finally, add Cesium Sun Sky lighting and Floating Pawn for cool sunlight illumination of outdoor scenes and free viewpoint navigation for quick real-earth environment building.

2.3.3 Load the BIM model to enrich scene elements

Before the BIM model is imported into Unreal Engine 5, you need to make sure that the size unit of the model is‘cm’,and export the BIM model to FBX format to be imported into Unreal Engine 5 via Datasmith importer. Later on, scene refinement, vegetation supplementation, and writing interactions can be carried out in Unreal Engine 5, for example, using directional light sources, point light sources, spot light sources, rectangular light sources, and sky light sources for scene light production, and adjusting specific parameters for detailed processing of the scene's lighting.

3.Application situation

3.1 Digital Retention

Digital retention for the protection of monumental buildings mainly lies in three points. Firstly, compared

https://doi.org/10.37420/j.adr.2024.012

with traditional two-dimensional plane material retention, digital retention can be more intuitive and detailed to save the overall data of the building. Secondly, the digital retention of modelling, model collision test for the existing two-dimensional plane drawings can be information proofreading and correction, to reach a more accurate data retention and to achieve the update of two-dimensional plane drawings [10]. Finally, digital retention can put a large amount of building information on the same computer; the horizontal and vertical comparison of building development will be clearer and more intuitive.

3.2 Promotion of protection

Monumental architecture digital protection has interactivity not other traditional media. The user can roam, in accordance with the map to walk in virtual space through the digital technology will monumental architecture static display into dynamic, endowed with sound and light, and then the use of national memorial architecture media film and television technology, giant-screen projection technology, multi-touch technology to enrich the form of the display to enhance the browsing and display of interactive (As shown in Figure 12). For example, for revolutionary monumental architectures, sand table games simulating battles can be established in the revolutionary war sites, and 3D perspectives can be set up for visitors to be immersed in the scene and feel the charm of the revolutionary spirit more deeply. Such an innovative way of displaying not only allows people to understand the occurrence of historical events but also inspires them to identify with and understand the spirit of the revolution, strengthening the country's unity and cohesion.

Figure12. VR Experience

4. Conclusions

This paper utilizes Building Information Modeling (BIM) to achieve parametric modeling of architectural components. By integrating existing data and the results of multiple on-site surveys, the building components' data, materials, and construction techniques are collectively expressed, and the structural data relationships are standardized and correlated. Taking the Siming Mountain Martyrs' Mausoleum in Zhangcun as an example, the monument model constructed through these means largely conforms to the physical structure. However, while BIM technology alone achieves information collection, the models may lack realism. Therefore, rendering is introduced to enhance the model's aesthetics and authenticity. Building upon the foundation of BIM model rendering, the application of Virtual Reality (VR) technology to virtual models of national memorial architecture offers users a more immersive experience and interactivity, aiding in their better understanding and appreciation of the history and value of such structures.

The digitization of national memorial architecture through the integration of Building Information Modeling (BIM) and Virtual Reality (VR) technologies represents a novel approach. This approach not only comprehensively preserves the architectural model information of commemorative buildings but also facilitates their promotion in virtual spaces, greatly enhancing spiritual dissemination. By utilizing BIM technology to

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construct models of national memorial architecture, preserving and maintaining data, and showcasing the overall effects through VR virtual technology, the integration of these two technologies achieves a more faithful representation of the original appearance and spirit in virtual spaces, thereby achieving better promotional outcomes.

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