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Documentation and Preservation of Cultural Heritage Submerged by Dam Construction Using Digital Technology

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Abstract

The proliferation of hydropower dams has submerged numerous cultural heritage sites, posing significant challenges to their preservation and study due to physical inaccessibility and accelerated deterioration. This paper explores the potential of digital technology in documenting and reconstructing such submerged cultural heritage, specifically focusing on the Daegok-ri Bronze Age site in South Korea. Utilizing GIS-based landscape analysis, 3D visualization, and real-time rendering engines, this paper digitally reconstructs the site's historical landscape and the spatial context of its features.
This digital reconstruction clarifies the relationships between dwellings and tombs, providing crucial archaeological insight. These outcomes also facilitate virtual heritage applications for educational programs, museum exhibits, and virtual tourism through VR/AR. Ultimately, this approach demonstrates digital preservation as a sustainable solution to record, protect, and reimagine submerged heritage through immersive virtual environments.

1. Introduction

1.1 Background

Dam construction has been instrumental in water management and regional development, particularly in South Korea, where approximately 18,000 hydropower dams and reservoirs have been established since the 1970s (Ingyeong, 2023). These vital structures, while essential for supporting agriculture, industrial development, and flood management, often result in the submergence of irreplaceable cultural heritage.
The preservation and study of submerged heritage are severely challenged by physical inaccessibility, rapid deterioration in water, and the limitations of traditional methods.

1.2 Research Objectives and Scope

This paper aims to explore digital methods that preserve and reconstruct such submerged heritage, ensuring their continued relevance and accessibility. As a preservation method, representation (or reconstruction) visually reassembles a site by integrating its historical and environmental context (Lopez-Menchero and Grande, 2011). The proposed methodology emphasizes practical, accessible software and workflows that can be easily modified in the field (Hosun and Hyoungki, 2024). while also delivering user-friendly methods to mitigate technical challenges.

2. Context and Challenges of Submerged Heritage

2.1 Definition and Significance of Documentation for Submerged Heritage

Documentation involves recording a site's condition, structure, and spatial context before it is lost. Techniques such as photography, measured drawings, and 3D modeling play a central role in this process, offering precise and multi-dimensional records that serve as long-term resources for scholarly inquiry, restoration, and management. In the context of submerged heritage, where physical access is often limited and sites are subject to continuous environmental deterioration, these digital techniques become especially critical. They enable the creation of accurate visual and spatial datasets that capture the site's state at a specific moment in time.
Importantly, such documentation not only preserves the site's value and narrative after physical disappearance but also establishes a scientific baseline for monitoring changes over time. By allowing for comparative analysis and informed conservation planning, digital documentation transforms from a passive recording tool into an active instrument for preservation. Thus, the definition of documentation extends beyond simple archiving—it encompasses a technologically driven, forward-looking approach to safeguarding cultural heritage in fragile and inaccessible environments.

2.2 Case Studies of Heritage Affected by Dam

Globally, several significant heritage sites have been affected by dam construction.
In Luang Prabang, a UNESCO World Heritage Site in Laos, the proposed Nam Ha Con (Ha Kong) Dam project poses significant threats to its outstanding cultural and historical landscape. UNESCO has expressed concerns that, without adequate mitigation measures, the dam may lead to the site's removal from the World Heritage List. The Temple of Abu Simbel, once threatened by the Aswan High Dam, was successfully relocated and reassembled with the help of UNESCO. Ashur, the ancient capital of the Assyrian Empire, is currently at risk of being submerged, prompting the need for urgent digital recording. In Hasankeyf, a historic city on the Tigris River, some structures have been submerged, while others have been preserved, though additional conservation is still required.

Site Name	Country	Excavation Year
Town of Luang Prabang	Laos	2000s
Abu Simbel Temples	Egypt	1960s
Assyrian City, Ashur	Iraq	1970s-2000s
Hasankeyf	Turkey	1980s-2000s
Daegok-ri Bronze age site	Korea	1980s

Table 1. Cases of Sites Affected by Dam Construction

In Korea, a similar issue is found at the Daegok-ri site in South Jeolla Province. Known for its dense concentration of Bronze Age pit dwellings and dolmens, the site has been submerged due to dam construction. Today, its remains are visible only during periods of low water, underscoring the urgency of preservation through digital methods.

2.3 State of Digital Documentation

While prominent international sites (See Table 1) are undergoing 3D scanning and digital archiving, Korea's Daegok-ri site significantly lacks comparable documentation efforts. Furthermore, the digital preservation of submerged archaeological sites in Korea remains in its early stages, with few comprehensive initiatives currently in place. While 3D scanning has proven most effective at well-preserved and easily accessible sites, documenting already damaged or previously excavated locations often relies solely on archival sources such as excavation reports and field notes.

In contrast, international cases (See Table 2) illustrate how advanced technologies—like photogrammetry and sonar scanning—enable the effective digital preservation of submerged heritage. These efforts benefit from strategic planning and institutional support, which remain limited in Korea. To address this gap, Korea must develop a coordinated national strategy that advances underwater documentation technologies and fosters interdisciplinary collaboration.

Site Name	Country	Documentation Techniques
Pavlopetri	Greece	Photogrammetry
Thonis-Heracleion	Egypt	Side-scan sonar
Nymphaeum	Italy	Optical scanning, Photogrammetry
Bouldnor Cliff	UK	Digital documentation
Atlit Yam	Israel	Partial 3D documentation
Puck Lagoon	Poland	LiDAR-based DEM

Table 2. Cases of Digitally Documented Submerged Sites

3. Digital Documentation and Reconstruction Methodology

3.1 Overall Methodological Framework

Figure 1 illustrates a four-stage digital reconstruction process for heritage Landscapes , presenting a methodological approach to digitally document, model, and interpret a specific site.

The first stage is data acquisition, which involves collecting archaeological data, topographical data, and environmental information related to vegetation from the site. The crucial aspect here is to ensure accurate and reliable information is gathered from diverse data sources.

The second stage is the reconstruction of past topography and environment. This utilizes 3D modeling, paleo-topography, and GIS-based analysis to recreate the Bronze Age topography and vegetation. It is important in this stage to not only base the reconstruction on archaeological estimations but also to realistically restore the surrounding environment.

The third stage focuses on the reconstruction of heritage features. This involves implementing the form, structure, and arrangement of archaeological features, such as dwellings and tombs, based on academic evidence.

The final stage is the interpretation and assessment of the visualized data's potential applications. This involves integrating the visualized data to interpret the context of the landscape and archaeological features, and evaluating its potential uses. This work goes beyond simple preservation, helping to visually convey the background and significance of the heritage site, thereby expanding its academic, educational, and public value.

In addition, Table 3 lists the main software tools used throughout the digital reconstruction process. These software support digital reconstruction through 3D modeling, graphic creation, spatial analysis, and visualization, providing the technical foundation necessary to implement each stage effectively and ensure both precision and coherence in the final output.

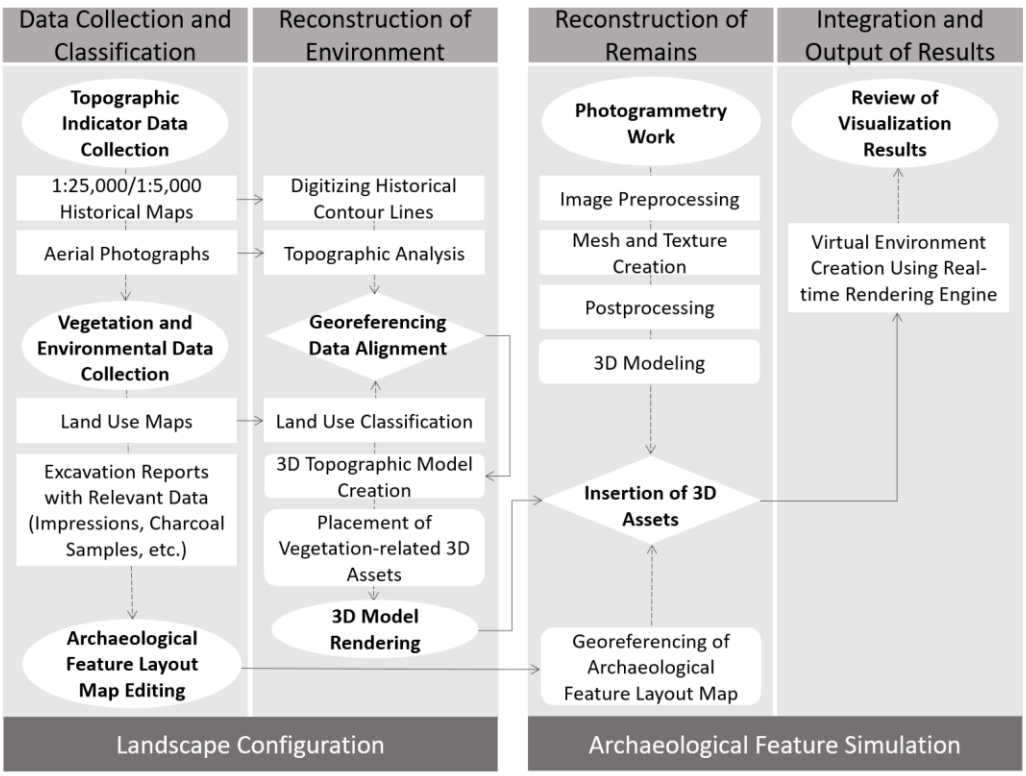

Figure 1. Methods and Process of Digital Reconstruction of Archaeological Landscape

Software Name	Purpose	Notes
Reality Capture	Photogrammetry	Free for sales under
TwinMotion	Visualization	US $1,000,000
ArcGIS	GIS Analysis	ESRI (or QGIS)
Blender	3D Graphics	Free

Table 3. Software Utilized in the Process

3.2 Digital Reconstruction Workflow

3.2.1 Topographical Environmental Reconstruction

To reconstruct the historical landscape, topographic maps from 1972 (1:25,000 scale) were first geo-referenced within a GIS environment, followed by the assignment of a coordinate system. The relevant map sheets included Boknae, Namnae, Dongbok, and Juam. Contour lines from these maps were digitized and, together with spot height data from 1986 1:5,000 topographic maps, used to generate a high-resolution Digital Elevation Model (DEM). The resulting model is illustrated in Figure 2. These elevation datasets were processed using ArcGIS to produce a precise 3D terrain model that reflects the paleo-topography, including slope, altitude, and landscape variation.
Given that mountainous and hilly areas showed little change after the construction of the Juam Dam, the 1986 map data was considered suitable for reconstructing these terrain features. Digitizing involved converting analog contour information into digital shapefiles (.shp), which allowed for integration and spatial analysis within the GIS system.
The final terrain reconstruction, rendered in 3D using ArcGIS and supplemented by historical aerial imagery, provided a detailed and realistic representation of the past environment. This process enabled a better understanding of the interactions between natural settings and human activity, and allowed for visual interpretation of the transformation of the archaeological landscape over time.

3.2.2 Feature Visualization and 3D Asset Creation

For 3D model creation and environmental composition, Blender was used to generate terrain data based on DEMs produced in GIS. The elevation data was processed to reflect slope, altitude, and key landform characteristics, forming the foundation for three-dimensional modeling. Blender’s advanced tools allowed for detailed editing, supporting the accurate representation of geomorphological features derived from GIS analysis.
The modeled terrain was then imported into TwinMotion, a real-time rendering engine known for its intuitive and accessible and visually rich interface, to visualize the landscape. Historical aerial imagery and geomorphological analysis informed the delineation of river boundaries and flow directions, which were depicted using directional flow effects. Features such as river terraces and natural levees were shaped with stepped gradients and leveled surfaces to simulate habitable areas and hydrological dynamics.
Further landscape elements were added based on paleo-topographic data and land-use records. These included flood-safe rice fields, colluvial slopes, water sources, and forest zones. TwinMotion’s asset library provided a wide range of 3D elements, enabling the placement of vegetation such as chestnut and pine trees, along with agricultural areas like paddy fields (see Figure 3). Environmental settings—such as lighting, weather, and time of day—were finely tuned to enhance visual coherence and spatial context.
Through this integrated workflow, Blender and TwinMotion facilitated a vivid reconstruction of historical landscapes and settlement environments. The resulting 3D visualizations allowed for the interpretation of spatial relationships and subtle topographic features—such as elevation differences and drainage patterns—that are often obscured in conventional 2D mapping. This process offers valuable insights into how ancient communities interacted with and adapted to their physical surroundings.

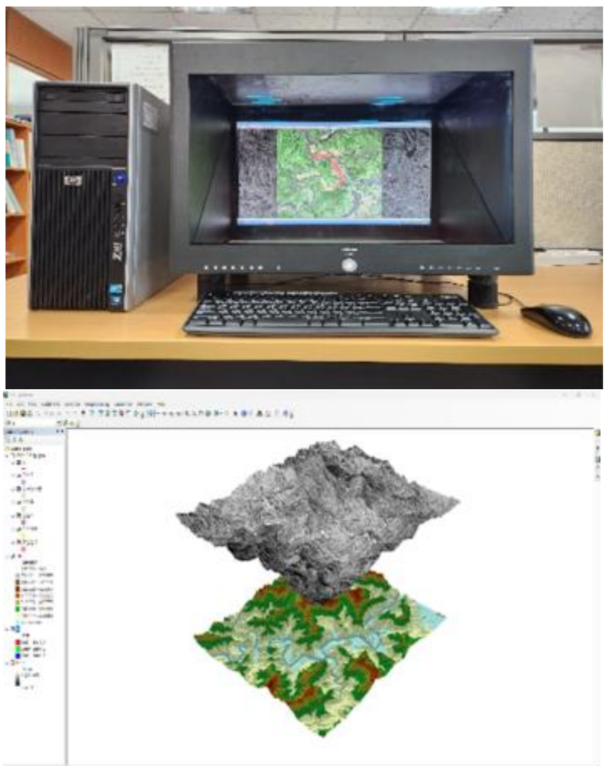

Figure 2. Analysis of Topography Using Aerial Photographs and Creating of DEMs on GIS

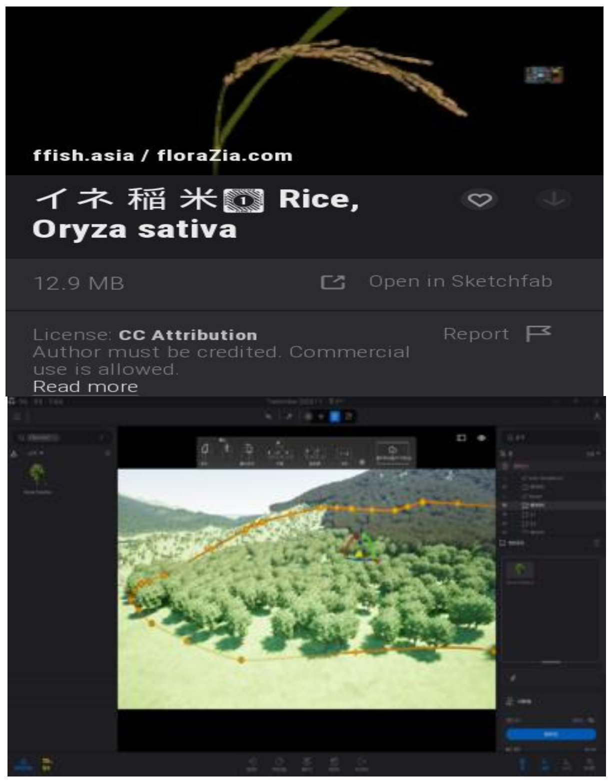

Figure 3. List of Vegetation-Related 3D Assets in the TwinMotion library and Inserting 3D assets

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3.2.3 Archaeological Feature Modeling and Photogrammetry

A total of 69 dwellings and 15 dolmens were excavated from the Daegok-ri site in Suncheon. Some of these features were relocated and restored at the Suncheon Dolmen Park. In the park, reconstructed models of Pit House No. 2 and No. 5 from the Bronze Age, originally excavated from the Dorong District, are currently on display. Archaeological feature modeling incorporated existing reconstructed pit dwellings and dolmens at Suncheon Dolmen Park (see Figure 4). In the Rome Reborn Project, diorama data recreating Rome was acquired and used for virtual site restoration utilizing 3D scanning (Dylla et al., 2010; Wells et al., 2010).

Figure 4. Display of Bronze Age Pit Houses at Suncheon Dolmen Park and Photogrammetry-Based Image Captures

Multiple photographs of the features were first taken from various angles. Photogrammetry software (Reality Capture) was then used to extract common feature points from the photographic data. Based on these points, the images were aligned, and camera positions and orientations were calculated to generate a 3D point cloud. A high-resolution 3D mesh was then reconstructed from the point cloud to produce a complete digital model (see Figure 5).

The resulting model accurately preserves the geometry and scale of the original features and can be imported as a 3D asset into real-time rendering software. Therefore, photogrammetry was employed to generate accurate 3D models of these features from photographic data, offering a cost-effective and efficient method particularly for capturing large areas and detailed textures.

To ensure accurate spatial positioning, georeferencing was performed based on archaeological feature layout maps from the excavation report. These were aligned with historical aerial photographs, old maps, and digital topographic data. Using the resulting spatial framework, pit dwellings and dolmens were positioned within the reconstructed terrain model to reflect the site's topographical characteristics.

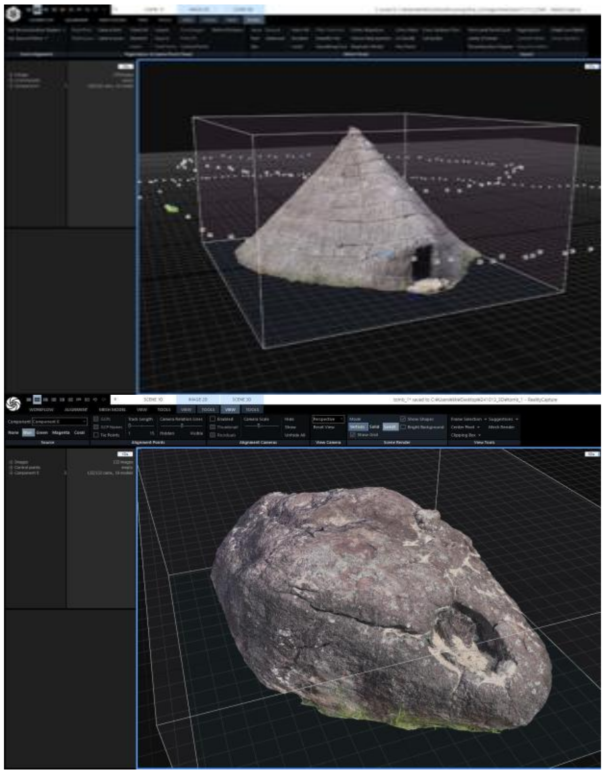

Figure 5. Inserting Photogrammetry Data for Dwelling and Tomb sites

4. Results and Discussion

4.1 Archaeological Insights from the Reconstructed Landscape

4.1.1 Spatial Organization and Terrain Utilization

The digital reconstruction of the Daegok-ri site in Suncheon provides valuable insight into how people in the Bronze Age utilized the landscape and adapted it to their daily lives. Located on river terraces along the Boseong River, the site's broad and level topography suggests it was well-suited for large-scale settlement and agriculture.

The settlement area is arranged in a linear pattern approximately 40 meters from the river, a layout that appears to balance easy access to water resources with the need to avoid flood risk. Dolmens were constructed near pit dwellings, forming small burial clusters within the residential zone, while some graves were placed on elevated colluvial slopes. This spatial arrangement implies a conscious separation between domestic and symbolic spaces, likely based on topographical considerations (see Figure 6).

The reconstruction also enables visual interpretation of agricultural and environmental conditions. Rice grains discovered in the base of a coarse pottery vessel from Pit House No. 40-1 indicate that rice was cultivated at the site (National Gwangju Museum, 1990). Additionally, charcoal samples from a nearby dwelling (House No. 3) at the Gokcheon site revealed chestnut species, suggesting that wild plant resources were gathered from surrounding forests (Chonnam National University Museum, 1988).

Lastly, the surrounding hills and uplands were likely covered with mixed deciduous and evergreen forests, offering a variety of plant and animal resources. Certain cultivated plots may have taken advantage of favorable soils for tree planting, indicating a practical use of natural and semi-managed environments.

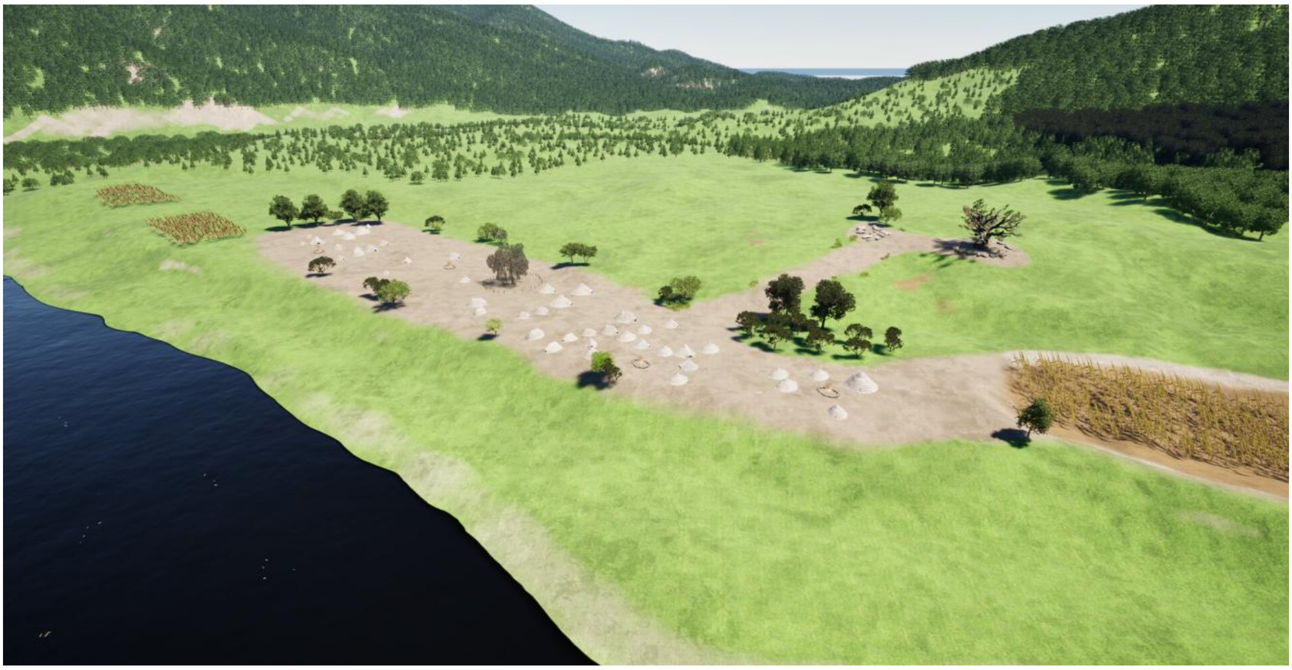

Figure 6. Digital Reproduction Results of the Bronze Age Settlement at the Daegok-ri site in Suncheon

Figure 7. Digital Reproduction Results of Residential Area

Figure 7 presents a reconstruction of the residential area. The identification of 69 overlapping pit dwellings suggests long-term occupation of the site. This indicates that the settlement at the Daegok-ri site in Suncheon, which was continuously inhabited from the 8th to the 3rd century BCE (Jaehoon, 2022), was closely tied to favorable topographical conditions—such as stable food production, wide visibility, and protection from natural disasters.

Figure 8 presents a reconstructed view of the burial area. The dolmen group is shown densely clustered along the colluvial slope, maintaining consistent spatial intervals. The long axes of the dolmens are aligned in a direction similar to that of the nearby river and are arranged in rows, suggesting an influence from the surrounding topographical conditions. Such an arrangement can be interpreted not merely as a geographical decision, but as a cultural expression rooted in a deep understanding of their environment.

The digital reconstruction clearly illustrates the livelihood activities and environmental adaptation methods of the people at that time. The possibility of rice cultivation on natural levees, the utilization of mountain resources, and active fishing evidenced by fishing weights indicate stable food production and diversified subsistence strategies. The overlapping of dwellings suggests long-term occupation, prompting a reflection that the site's locational characteristics were intrinsically linked to the community's ecological adaptation and spatial utilization strategies (Ingyeong and Hyoungki, 2025). These findings collectively made it possible to virtually revive the landscape of the submerged area, offering a meaningful reconstruction of a site that is no longer physically accessible.

Figure 8. Digital Reproduction Result of Burial Area

4.2 Implications and Future Prospects of Digital Preservation

Academically, digitally reconstructed heritage provides visual insight for archaeological interpretation. Practically, they enable applications in virtual reality (VR), augmented reality (AR) for education and exhibitions, as well as immersive extended reality (XR) content for virtual tourism and cultural heritage preservation. For instance, in India, the UNESCO World Heritage site of Hampi temples that have been visually reconstructed using surveying and 3D modeling for VR (Natampally, 2014). Looking forward, digital preservation technologies are expected to play a pivotal role in the sustainable management and ongoing engagement with submerged and at-risk cultural heritage sites.

5. Conclusion

This paper presents an effective model for documenting and reinterpreting submerged cultural heritage through the digital reconstruction of the Suncheon Daegok-ri site. By combining archaeological data with digital visualization, this approach contributes to digital preservation and broadens its application in heritage management.

However, given limited historical data, reconstruction takes an interpretive approach, requiring ongoing discussion and evaluation. This paper's digital reconstruction is also an interpretive process based on current archaeological and research data, not a complete restoration of the past. Digital technology is a powerful tool for heritage preservation, but its use demands careful academic scrutiny and continuous development efforts.

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