Augmented Reality (AR) Technology-based Digital Restoration of the Middle Gate in *Hwangnyongsa* Temple Site of the 8th Century *Silla* Dynasty Period

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Keywords: *Digital Restoration — Augmented Reality — Ancient Architectural Site —Hwangnyongsa*

CHNT Reference: Kwon, H., Han, W. and Seo, H. (2021). 'Augmented Reality (AR) Technology-based Digital Restoration of the Middle Gate in Hwangnyongsa Temple Site of the 8th Century Silla Dynasty Period', in CHNT – ICOMOS Editorial board. *Proceedings of the 26th International Conference on Cultural Heritage and New Technologies.* Heidelberg: Propylaeum.

Academic Research on Hwangnyongsa Temple and Digital Restoration

Hwangnyongsa Temple was first built in 569 on the east side of *Wolseong* area in *Gyeongju*, the capital of *Silla* (now near *Guhwang-dong*, *Gyeongju-si*, *Gyeongsangbuk-do*, Republic of Korea). It was destroyed by fire during the Mongol invasion of 1238, and only the site remains these days. The excavation of *Hwangnyongsa* Temple started in the late 1970s and has continued to the present, and research on restoration of buildings started in 2007. Since 2016, research on the structure, design, and construction techniques has been bolstered to restore the Middle Gate. Also, the feasibility study has been carried out by producing a 1:20 model, design drawings, and 3D modelling. Professional consultations, field investigations, and discussions have persisted, and in 2017, a basic design proposal for the restoration of *Hwangnyongsa* Middle Gate based on BIM (Building Information Modelling, Autodesk Revit-based) was prepared. Meanwhile, it was decided to restore the Middle Gate digitally, and from 2018 to 2020, Augmented Reality (AR) content was produced using these BIM modelling data.

a *b* *c*

Fig.1. Hwangnyongsa Middle Gate Restored through AR Technology
a) Site of Hwangnyongsa Middle Gate b) and c) Augmented digital model at the site

Development of Augmented Reality Content for *Hwangnyongsa* Middle Gate

Augmented Reality technology has been adopted as the new means of sharing digital restoration results with the public. Considering portability, real-time experience, and visitors' convenience, the research team decided to prepare mobile devices for the on-site experiment. To overcome the limitations of the existing AR technology, the main objectives of this project aimed for precise location matching and realistic expression. In terms of the device, 12.9-inch iPad Pro tablets were selected for optimal display visibility and immersion on-site.

Applied Technology

Optimization of Modelling Data and Real-time Rendering Process

To optimize the processing speed of digital modelling data, a method of adjusting the Level of Detail (LOD hereafter) was applied. The range of the model's LOD was broken down into different levels, and LOD group components with optimized capacity were developed and applied for each level. In addition, the sequence of the rendering process was optimized by modularizing the repetitive modelling elements. Modularized members are either transformed into mesh again or instanced to optimize the speed at which the entire model is realized on the device.

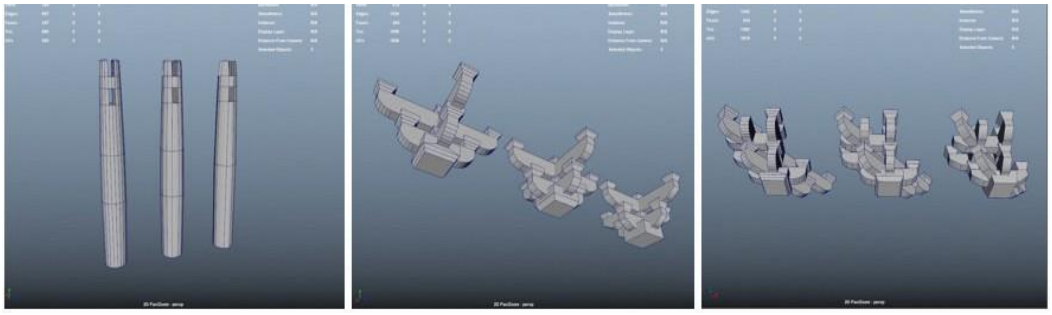
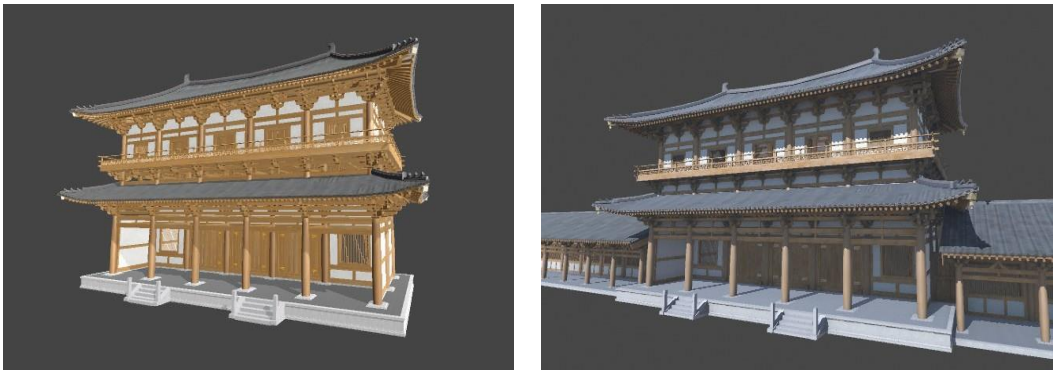


Fig. 2. 3-step modelling process in which static LODs are applied

Technology Development for Realistic Expression

The texture of the materials and accurate shadow casting were critical for the realistic expression of the architectural ruins. PBS (Physical Based Shader) was applied for realistic rendering of wooden structure, and the texture mapping source was also reproduced to match the features of PBS. Also, the orientation of shadow of the digital model is devised to match that of the real environment. Since the position of the sun varies according to time and date, the changing position of the sun over a year at the site was programmed to be applied in real-time.



a b

Fig. 3. Experiment for Realistic Expression a) Before PBS applied b) After PBS applied

Precise Location Matching

The precise location matching could be achieved by combining the camera location tracking method and the marker method using a SLAM-based system (ARKit in iOS) instead of using the existing GPS. The image marker recognition algorithm was upgraded to improve the error rate and solve the cumulative error. The error rate could be highly reduced by installing several markers on-site and letting the users directly match their exact location by selecting nearby markers. Since the location information of each marker should vary, each marker has a unique pattern to contain specific location information.

Significance

This project has notable significance in that it confirmed the potential of digital content as a tool that can translate academic research results into contents for the public. Above all, considering the flexi ble and fungible features of digital content, such a project can allow continual updates. This project can contribute to the new and universal means of enjoying the ancient architectural ruins that disap peared. We hope that this achievement will serve as a meaningful reference for the digital restorati on of architectural relics in various parts of the world.

Funding

This work was supported by the National Research Institute of Cultural Heritage (NRICH) in Korea (NRICH-2105-B01F).

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