The 3D reconstruction and visualization of Seokguram Grotto World Heritage Site

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***Abstract*— Seokguram Grotto is the most notable heritage site of the Shilla dynasty, representing the Buddhist rock art with various architectural, mathematical and geometrical skills. Owing to its universal value and a representative masterpiece of Buddhist culture around the world, it was listed as a World Heritage Site in December 1995 under the UNESCO World Heritage Criteria for Selection. Due to its enormous cultural significance and diverse location, the site witnesses various environmental conditions and tourism pressure which affects its prestigious status and sustainability. This raises the need of a 3D reconstruction and visualization, and presentation. 3D scanning approach is a generally accepted technique for the collection of 3D representation of heritage sites. For this reason, the laser scan technology was extensively used by measuring 3D surface coordinates to produce a complete 3D digital replica of Seokguram Grotto. Particularly, laser scanning technique was used to collect various 3D scan data, featuring high data acquisition rates, good accuracy and high 3D data density. The scan data were then optimized to produce geometric accuracy and visual quality of the collected textured 3D models. Our approach has enabled us to produce a complete 3D stereoscopic exhibition of Seokguram Grotto.**

Keywords—Seokguram Grotto; 3D reconstruction; 3D visualization; 3D scanning;

I. INTRODUCTION

Seokguram Grotto is an artificial stone grotto at the top of mountains of Toham in Gyeongju, South Korea. Owing to its universal value and a representative masterpiece of Buddhist culture around the world, it was listed as a World Heritage Site in December 1995 under the UNESCO World Heritage Sites criteria for selection [1, 2]. Seokguram Grotto is a well-renowned national treasure of South Korea. The structure of Seokguram Grotto represents Buddhist art with various architectural, mathematical and geometrical skills [3].

Seokguram Grotto is a major historical site in Gyeongju and the core of Korean Buddhist culture. The site is a noble monument of divinities symbolizing Buddhist philosophy, and an inspired attraction of religious belief, science and arts, which blossomed in the golden age of Asian Art [4]. However, the site endures various environmental conditions and tourism pressure, because the grotto is made of white granite stones, creating a round-domed chamber that appears as an earth-covered cave [5] at the top of a mountain [See Fig. 1a and Fig. 1b]. This raises the need of digital preservation and a complete 3D digital replica of its original appearance. The existing laser scanning technique has been extensively used to produce a 3D digital replica of Seokguram Grotto. The resulting visualization aims to explore its enormous cultural, scientific and religious significance to the wider audiences.

Fig. 1a. Exterior view of Seokguram Grotto from the top of mountains of Toham

Fig. 1b. The inside view of Seokguram grotto

II. 3D RECONSTRUCTION AND VISUALIZATION

The most common approach in working with 3D a reconstructed heritage site is to use the existing 3D scanning technologies with 3D modeling tools. Using this approach, data can be acquired, preserved, and passed down to future generations [6]. Such data can also be used to restore and visualize real heritage objects in the event of damage. In addition to the reconstruction, there are several methods of visualization and exhibitions, such as hand drawn typography and walk-through displays, computer aided design, geographic information systems, 3D animation and virtual reality techniques, 3D stereoscopic presentations, augmented reality applications and web 3D applications. These tools and methods are listed as follows:

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A. Digital Photogrammetry

It is simple and low cost method used in cultural heritage documentation and acquired different extensions of digital images obtained from digital cameras. These digital images provide direct data flow and quality control for automation and required topographic support for the best geometric features in Photogrammetry applications [9]. Australis Photometric software and Leica Photogrammetry Suite are the key examples. The combined suite of laser scanning and Photogrammetry is also available for high performance measurement, such as Atos II scanner, Gom GmbH, Germany [8].

B. Laser scanning technique

Laser scanning technique is a fast and efficient method that automatically collects 3D coordinates of tangible cultural heritage. Various laser scanners measure the direction of optical lines connecting points on the surface of cultural heritage objects to reference points on the measuring device and produce Cartesian coordinates [11, 9]. The major weaknesses of laser scanning techniques are cost and safety controls associated with the use of laser source, for example, Vivid system [Konica Minolta, Inc.], and Leica Scanstation.

C. 3D animation and virtual reality

This technique is capable of providing an efficient virtual reconstruction environment of real objects and multimodal interaction, for example a video game experience [10].

D. Augmented reality and Web 3D

Augmented reality provides a natural view of real scenes by blending virtual environment through video processing and computer vision techniques. AR systems offer immersive interactivity and enable the visualization of 3D models of cultural heritage objects. Web 3D applications are web contents, encapsulated in X3D prototypes used for short scenes, which enhance the web experience and provide the best overview of cultural objects [13].

E. Stereoscopic presentation

Stereoscopic presentation is a visual presentation of virtual objects that provides a high accuracy stereo vision and enables the realization of virtual environment by pinpointing realistic feelings of immersion in the virtual system [14, 8].

F. 4K ultra high definition immersive presentation

The 4K ultra high definition has 4X resolution that enables users to perceive a great immersive experience of cultural heritage objects.

G. 3D reconstruction suites

3D cultural heritage objects can be modeled using 3D reconstruction softwares, such as AutoCAD, Maya, 3D Studio Max and MultiGen Creater [12]

H. Geographic information systems

Geographic Information Systems store, manipulate and manage cultural sites and disseminate them as geographic visualization [10].

III. 3D RECONSTRUCTION AND VISUALIZATION OF SEOGKURAM GROTTO

Various 3D reconstruction tools were used to produce a complete 3D digital replica of Seokguram Grotto. These tools include, Konica Minolta Vivid 9i state-of-the-art 3D scanner and Leica Scanstation P20 3D scanner with RapidForm XOS suite, Maya, 3D-Studio Max, and a Mesh buildup wizard. The combination of such tools yielded a common 3D coordinate system from the scan points. The whole process is described below in three stages:

First, a Leica 3D scanner was used to capture three-dimensional data of the grotto. The data were then imported into 3D modeling tools for creating 2D and 3D drawings (see Fig. 2a). For short-range scan data, a Vivid 9i 3D scanner was used. Likewise, respective drawings of the Shrine were achieved from long-range scan data, as the converted mesh was dense and unclear, hence the drawings were used to build mesh models.

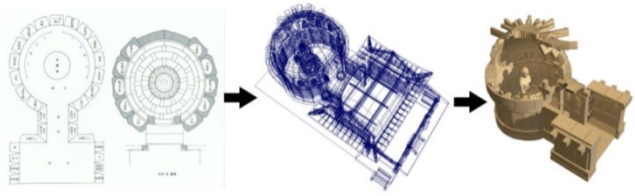

Fig. 2a. The process of 3D modeling of Seokguram Grotto

Secondly, scan data of the whole site were aligned and converted into watertight mesh models (see Fig. 2b). Colors and textures were added to the virtual objects. This technique was helpful to handle a large volume of scan data to rapidly create polygonal models and NURBS surfaces after alignment and merging process [15].

Fig. 2b. Watertight mesh modeling of the major statue

The volume of scan data was huge (approximately 40 gigabytes) including, billions of polygons. Therefore, the volume was reduced to four million polygons. In addition, the scan data was not compatible with the existing 3D reconstruction tools. As a result, the 3D contents of the inside view of Seokguram Grotto were generated for the 3D stereoscopic visualization. As shown in Figure 3, the resulting visualization includes, Seokguram Grotto's building stone structure, exterior wooden structure, and the 39 bas-reliefs.

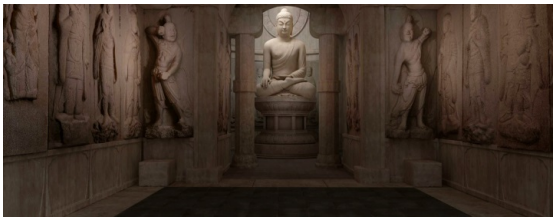

Fig. 3. The front view of the final modeling

Finally, The resulting visualization was used to produce a projection-based exhibition of Seokguram Grotto using Nova Trinity system that provides an immersive stereoscopic multi-channel display with nonlinear distortion correction and edge-blending capability (see Fig. 4a). The digital version of Seokguram Grotto was also produced, and presented in the "Silla: Korea's Golden Kingdom" exhibition, arranged by the Metropolitan Museum of Art, New York City in the USA. For this purpose, an Ultra-HD TV screen with ultra high definition native resolution of 3840×2160 pixels was used, which offers a great immersive visual experience to the visitors (see Fig. 4b).

Fig. 4a. Stereoscopic multi-channel display

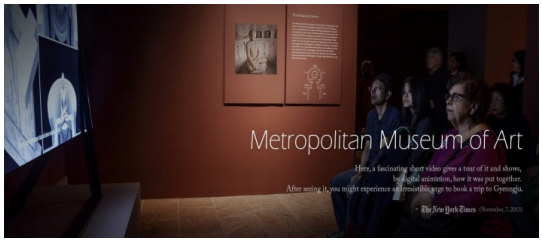

Fig. 4b. Ultra HD TV display at Metropolitan Museum of Art

IV. Emerging Trends in the Digital Seokguram Grotto

Using 3D scanning technique, three-dimensional data were recorded for the reconstruction and visualization of Seokguram Grotto. The initial trend of project-based immersive exhibition of Seokguram Grotto was produced using 3D stereoscopic vision. However, a more in-depth sense of immersion and perceived experience of a virtual heritage is still a challenging task for virtual heritage community. We came up with some new trends of virtual heritage applications for our future directions. We propose a projection-based immersive theatre, called CUBEDOM as an application for Seokguram Grotto. The CUBEDOM will replicate similar experience as the real Seokguram Grotto does, as it may have the same structure and size of Seokguram Grotto. The proposed prototype is shown in Figure 5. We also propose a head-mounted display system for more immersive and interactive environment by providing gesture-recognition interfaces to provide a consistent user interaction with virtual objects (see Fig. 6).

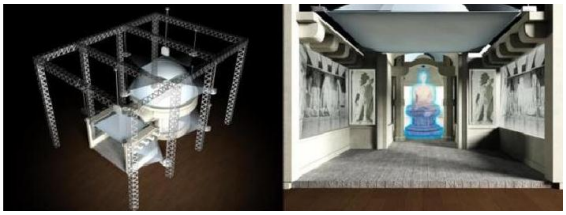

Fig. 5. CUBEDOM immersive theatre

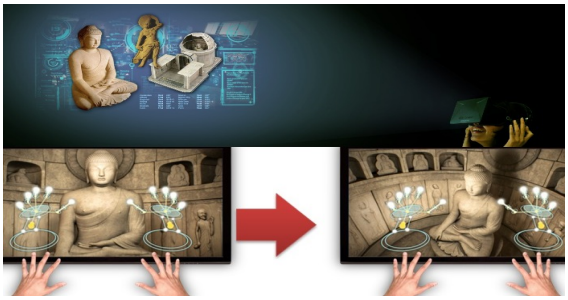

Fig. 6. Head mounted display system prototype

V. Conclusions

The paper presents a complete process of 3D reconstruction and visualization of a heritage site for its digital exhibition. Using 3D scanning technologies, the three-dimensional data of a heritage site were collected. Various reconstruction techniques were applied to produce 3D models and then visualization techniques to demonstrate an accurate representation of a heritage site. The overview of the state-of-art on digitization scheme proposed in this study yields a number of inclusive remarks. Firstly, the cost of tools for scanning and 3D reconstruction. Most of the tools available are still expensive. This shows a barrier to a considerable extensive use of the 3D scanning methods. Second, the use of 3D scanners is complex, and professionals are required to operate them. Thirdly, the problem of manipulating, editing and storing the acquired data from the 3D scanners, requires a powerful suite of 3D reconstruction tools, or the volume of data can be reduced for visualization to resolve compatibility issues associated with the tools. A final remark concerns the fact that 3D scanners in many complex and demolished heritage sites may not be successful when used alone. The concomitant use of Photogrammetry techniques, and 3D modeling and restoration through computer aided design may be necessary for complete digital reconstruction.

Given the above remarks, the future of 3D reconstruction and visualization of cultural heritage site exhibitions is indeed promising. Because, the use of 3D reconstruction for cultural heritage assets is dramatically increasing, and several developed and least developed countries have adopted to promote and preserve their cultural heritage.

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REFERENCES

[1] C. H. Lee, Lee, M. S. Suh, M. & S. W. Choi, "Weathering and deterioration of rock properties of the Dabotap pagoda (World Cultural Heritage), Republic of Korea." Environmental Geology, 2005, Vol. 47, No. 3, pp. 547–557

[2] A. Leask,and A. Fyall, "World heritage site designation. Managing world heritage sites.", 2006, pp, 5-19.

[3] M. Harrell, "Sokkuram: Buddhist monument and political statement in Korea." World archaeology, 1995, Vol. 27, No. 2, pp, 318–335.

[4] C. H Lee, S. W. Choi, & M. Suh, "Natural deterioration and conservation treatment of the granite standing Buddha of Daejosa Temple, Republic of Korea." Geotechnical & Geological Engineering, 2003, Vol. 21, No. 1, pp. 63–77.

[5] J-S. Suh, "World heritage in Korea." Hak Go Jae, 2001.

[6] K. Ikeuchi, T. Oishi, J. Takamatsu, R. Sagawa, A. Nakazawa, R. Kurazume, & Y. Okamoto,"The great Buddha project: Digitally archiving, restoring, and analyzing cultural heritage objects." International Journal of Computer Vision, 2007, Vol. 75, No. 1, pp. 189–208.

[7] M. Ioannides, E. Stylianidis, & S. Stylianou, "3D reconstruction and visualization in cultural heritage." In Proceedings of the 19th International CIPA Symposium, 2003, pp. 258–262, http://cipa.icomos.org/fileadmin/template/doc/antalya/72.pdf. Retrieved, 20/10/2014.

[8] G. Sansoni,M. Trebeschi, & F. Docchio, "State-of-the-art and applications of 3D imaging sensors in industry, cultural heritage, medicine, and criminal investigation." Sensors, 2009, Vol. 1, pp. 568–601.

[9] F. Remondino, "Heritage recording and 3D modeling with photogrammetry and 3D scanning." Remote Sensing, 2011, Vol. 3, No. 6, pp. 1104–1138.

[10] I. Alfano, & E. Pantano, "Advanced technologies for promotion of Cultural Heritage: the case of bronzes of Riace." Journal of Next Generation Information Technology, 2010, Vol. 1, pp. 1.

[11] A. Núñez Andrés, F. Buill Pozuelo, J. Regot Marimón, & A. de Mesa Gisbert, "Generation of virtual models of cultural heritage." Journal of Cultural Heritage, 2012, Vol. 13, No. 1, pp. 103–106..

[12] D. Koller, B. Frischer, & G. Humphreys, "Research challenges for digital archives of 3D cultural heritage models." Journal on computing and cultural heritage (JOCCH), 2009, Vol. 2, No. 3, pp. 7.

[13] M. Zollner, J. Keil, H. Wust, & D. Pletinckx, "An augmented reality presentation system for remote cultural heritage sites." In Proceedings of the 10th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST, 2009 (pp. 112-116). http://publica.fraunhofer.de/dokumente/N-111531.html. Retrieved, 20/10/2014.

[14] D. Gutierrez, F. J. Seron, J. A. Magallon, E. J. Sobreviela, & P. Latorre, "Archaeological and cultural heritage: bringing life to an unearthed Muslim suburb in an immersive environment." Journal of Cultural Heritage, 2004, Vol. 5, No. 1, pp. 63–74.

[15] J. H. Park, "Digital Restoration of Seokguram Grotto: The Digital Archiving and the Exhibition of South Korea's Representative UNESCO World Heritage." In Ubiquitous Virtual Reality (ISUVR), 2012 International Symposium on pp. 26–29. IEEE.