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Research Paper

Re-production of Digital Cultural Heritage and Acquisition of Two Dimensional Drawing Maps for the Cultural Heritage by the Reverse Engineering Technology

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Abstract

After the 'Guidelines for the preservation of digital heritage' were published by UNESCO, interests in the fabrication of digital cultural heritage have been increasing throughout the world. The present study was intended to fabricate digital cultural heritages for existing culturalpropertiesusing the reverse engineering technology and obtain two-dimensional drawings. Jinju Castle Gongbukmun, which is a cultural property, was selected as a study subject and 3D modeling of Jinju Castle Gongbukmun was conducted by implementing 3D scanning and processing the point cloud data. Using the Gongbukmun 3D model (3D-Gongbukmun) made as such, requirements as a digital heritage were reviewed and 2D drawings of Gongbukmun such as front views, ground plans, and side views could be prepared.

Keywords : Digital Heritage, Reverse Engineering, 3D Laser Scanning, 3D Modeling, Jinju Castle Gongbukmun

1. Introduction

Culturalheritages refer to those cultural products of society that have values high enough to be succeeded or inherited by the next generation or young generations for future cultural development. That is, cultural heritages include all of science, technologies, customs, norms, various mental/physical cultural properties, and cultural styles. Many countries designate those cultural heritages that have high historical/artistic values as cultural properties and make efforts to have them succeeded and developed. South Korea established the Cultural Properties Protection Act in 1962 and has been making efforts to preserve cultural properties too. The cultural properties under the Cultural Properties Protection Act collectively refer to tangible cultural properties that have high historical/artistic values or become materials for history studies out of the relics and remains left by our ancestors such as buildings, sculptures, artifacts, books, calligraphy, and ancient documents, intangible cultural properties with high historical/artistic values out of performances, dances, music, arts and crafts, and skills, monuments, and folklore materials.

Thepresent study was intended to fabricate cultural properties into digital cultural heritages using the reverse engineering technology and obtain two-dimensional drawings. Reverseengineering refers to a series of processes to obtain shape information from objects of which no drawing exists and fabricate two-dimensional drawings or three-dimensional models to utilize the outcomes in the preservation of original forms or product production. The area of reverse engineering that began to develop in the machine industry at first became to develop rapidly following the appearance of laser scanners that enabled precise three-dimensional modeling and the areas of application of reverse engineering became to be expanded to not only product manufacturing but also to the areas of digital restoration of cultural heritages and structure deformation monitoring.

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In South Korea, studies using laser scanners began to be active from 2000. In 2000, in his master's thesis, 'Analysis of cultural properties using photogrammetry and laser scanning systems', Han(2000) attempted to introduce laser scanners to the analysis of cultural properties and in a study in 2002 titled 'Verification of the accuracy of laser scanners and the creation of three-dimensional numerical models'(Lee, 2002), attempts were made to identify the accuracy of 3D model creation using laser scanners. In addition, studies to precisely measure cultural properties using a laser scanners combined withphotogrammetry were attempted by Jeong et al.(2003) and Lee et al.(2005). In 2007, a study for 3D modeling of ancient buildings using ground laser scanners was conducted by Lee et al.(2007) and in 2012, a study intended to compare the accuracy of photogrammetry and that of ground scanners for cultural properties was conducted by Bae(2012).

Meanwhile, while the 'Guidelines for the preservation of digital heritage' were published by UNESCO in 2003, study results regarding digitalcultural heritages were published in South Korea. In 2003, a paper regarding 'Digital restoration of cultural properties using the virtual reality technology' was published by Park and Yang(2003). In 2009, cases of digital restoration of domestic and overseas cultural heritages were introduced by Lee et al.(2009), and in 2010, a paper regarding 'Digital restoration of cultural archetypes' was published by Lee(2010). In 2013, discussions on digital cultural heritage began in earnest by You(2013) and in 2014, the results of a study on measures to acquire information on 3D laser scanning for application of reverse engineering of remodeling projects were published by Lee et al.(2014).

To review overseas research trends, after a study on 3D digitizing techniques was published by Pieracciniet et al.(2001), 3D digitization methods for cultural heritages were published by Pavlidiset al.(2007), and a paper titled 'Documentation of cultural heritage using digital photogrammetry and laser scanning' was published by Yastikli(2007).

2. Reverse Engineering and Digital Cultural Heritage

Reverse engineering is an integral process of considering technological specifications of an existing structure or product, or replicating an existing component as you can see in Fig. 1. It is one of the best techniques for optimizing designs and offering cutting edge solutions in 3D scanning, digitizing, measurement, and manufacturing support. To optimize designs and specifications of an existing product or structure, reverse engineering aids in: - Product re-engineering, Rapid prototyping, - CMM inspection and analysis, Digitizing, - Manufacturing drawings, - 3D visualization and animation, - 3D CAD modeling, - Mold surface analysis, - Measurement, - 3D laser scanning and conversion to CAD, - Manufacturability analysis, - Technical publication. The process of reverse engineering is used across different industries and applications, encompassing aerospace, heavy engineering, automobile and automotive, industrial equipment, military/defense, medical, and consumer products (Partel, 2014).

Heritage is explained in UNESCO documents as "our legacy from the past, what we live with today, and what we pass on to future generations." A heritage is something that is, or should be, passed from generation to generation because it is valued. The idea of cultural heritage is a familiar one: those sites, objects and intangible things that have cultural,

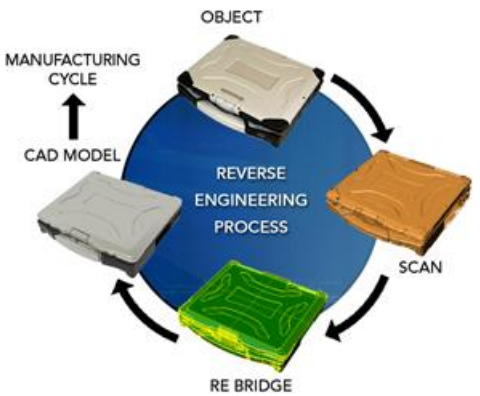

Figure 1. Reverse Engineering Process (Partel, 2014)

historical, aesthetic, archaeological, scientific, ethnological or anthropological value to groups and individuals. The concept of natural heritage is also very familiar: physical, biological, and geological features; habitats of plants or animal species and areas of value on scientific or aesthetic grounds or from the point of view of conservation (UNESCO, 2003).

Digital heritage is the use of digital media in the service of preserving cultural heritage(Kalayet als., 2008). The Charter on the Preservation of Digital Heritage of UNESCO defines digital heritage as embracing "cultural, educational, scientific and administrative resources, as well as technical, legal, medical and other kinds of information created digitally, or converted into digital form from existing analogue resources". Digital preservation consists of the processes aimed at ensuring the continued accessibility of digital materials. To do this involves finding ways to re-present what was originally presented to users by a combination of software and hardware tools acting on data. To achieve this requires digital objects to be understood and managed at four levels: as physical phenomena; as logical encodings; as conceptual objects that have meaning to humans; and properties of essential elements that must be preserved in order to offer future users the essence of the object(UNESCO, 2003).

3. Experimental Section for the Gongbukmun

To fabricate existing cultural properties into digitalcultural heritages and prepare two-dimensional drawings by reverse engineering, Jinju Castle Gongbukmun was selected as a study subject. Therefore, 3D Scanning of Jinju Castle Gongbukmun was conducted. The study process for fabrication of digital cultural heritages through 3D modeling and acquisition of 2D drawings is as shown in Fig. 1.

Jinju Castle was a soil castle under the late GoryeoDynasty and was reconstructed into a stone castle during the late Goryeo Dynasty and the early Joseon Dynasty. After Japanese invasions of Korea, whengenerals Kim Su and Lee Su-Il reconstructed the

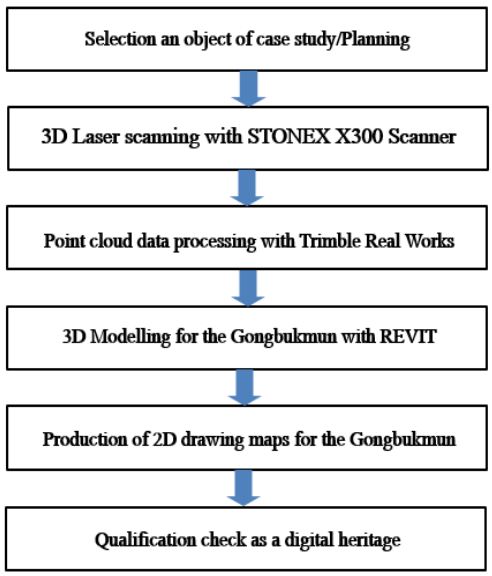

Figure 2. Reverse Engineering Process (Partel, 2014)

castle in 1603(Seonjo31), the castle was divided into an inner castle and an outer castle. Gongbukmun is a gate that corresponds to the north gate of the inner castle while being the front gate. This gate is assumed to have been built around the late 17th century and Gongbukmunrelated records are left in <Jinju Castle Diagram>, <Jinju Castle folding screen diagram>, and <Yeojidoseo>. 'Gongbuk' means that liegemen, who swore loyalty, bow politely toward the north where the king is. According to records, Gongbukmun was standing side by side with the ramparts and a two story castle was built above the arch of the gate. The castle was in a structure that had three rooms in front and the second floor was built with narrower rooms than the first floor. Since this was a gate that faced the king, it is assumed to have been intentionally built to be higher than other gates of Jinju Castle to have dignity. Gongbukmun was damaged in the late Joseon Dynasty, was investigated through excavation by Gyeongnam Institute of Cultural Properties in May and June 1996, and restored to the current shape on May 3, 2002. Currently, the height of Gongbukmun is 5.3m, the area of the first floor is approximately 66m², and the area of the second floor is 46㎡(Doopedia, 2016). Jinju Castle Gongbukmun was 3D scanned using a

Table 1. Technical performance of STONEX X300 laser scanner

Field of view	300m
Horizontal angle	360°
Vertical angle	90°(-25° to +65°)
Range	2～300m 100% reflectivity(on white)
Scan rate	Up to 40,000 points/sec
Laser beam divergence	0.37 mrad (horizontal and vertical)
Resolution range	18.5mm×37mm @100m
Accuracy	〈 6mm @50m ~ 〈 40mm @300m

scanner model STONEX X300 from Italy and the specifications are as shown in Table 1.

As can be seen in Fig. 3, the 3D Scanning was conducted at six points around Gongbukmun and the point cloud data obtained at individual points were matched to obtain the matched result as shown in Fig. 4. The point cloud data were created and processed using theTrimble Real Works software.

In addition, these 3D point cloud data were brought into the REVIT software to conduct 3D modeling in theREVIT. REVIT software is a BIM software of the Autodesk company delivers tools for architectural design, MEP engineering, structural engineering, and construction, and enables coordination between disciplines. Major processes of the 3D modeling conducted in the REVIT software are as shown in Fig. 4 and the individual stages were undergone as follows.

1) Set the position in REVIT software after importing the Gongbukmun 3D point cloud data
2) Set the level for the Gongbukmun 3D modeling in REVIT software
3) Floor modeling as a reference and then pillar modeling using the point cloud data
4) Stairs and banister modeling using in-place mass
5) Mass modeling to make the shape of the roof

Figure 3. 3D laser scanning picture(left) and the distribution of the laser scanning station(right)

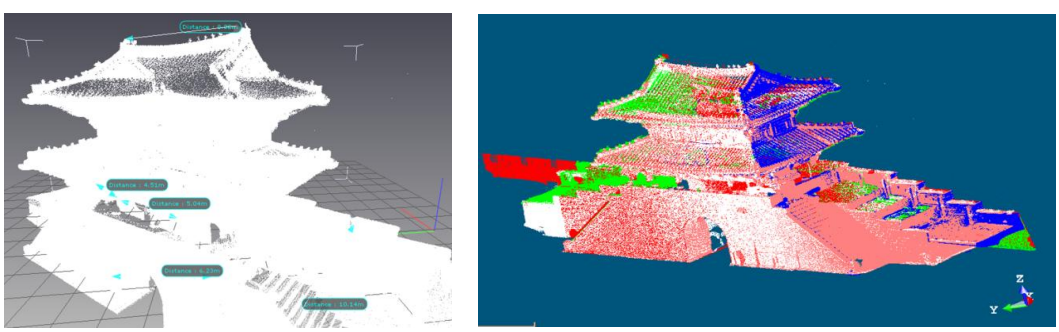

Figure 4. The processing of the 3D laser scanning point cloud data (left) and the results of the point cloud data matching (right)

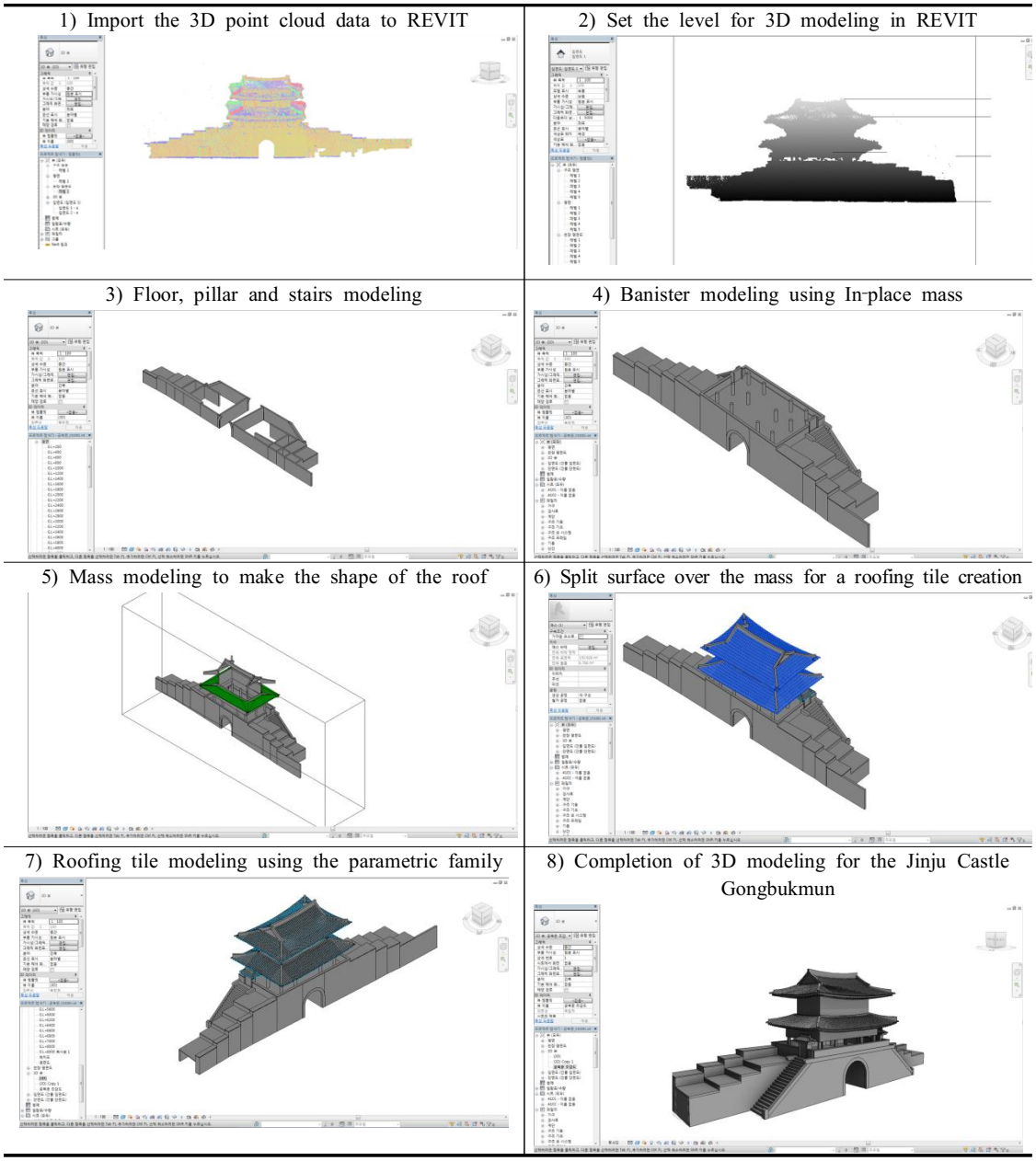

Figure 5. The main process of the 3D modeling for the Gongbukmun

6) Split surface over the mass for a roofing tile creation
7) Creation of parametric family to make the roofing tile and then roofing tile modeling
8) Completion of the 3D modeling for the Jinju Castle, Gongbukmun

The 3D model of Jinju Castle, Gongbukmun made as such was named 3D-Gongbukmun and 2D drawing maps could be prepared through reverse engineering utilizing 3D-Gongbukmun. The 2D drawing maps were prepared according to view angles under the names, plane map, front view map, rear view map, left side view map, and right side view map and

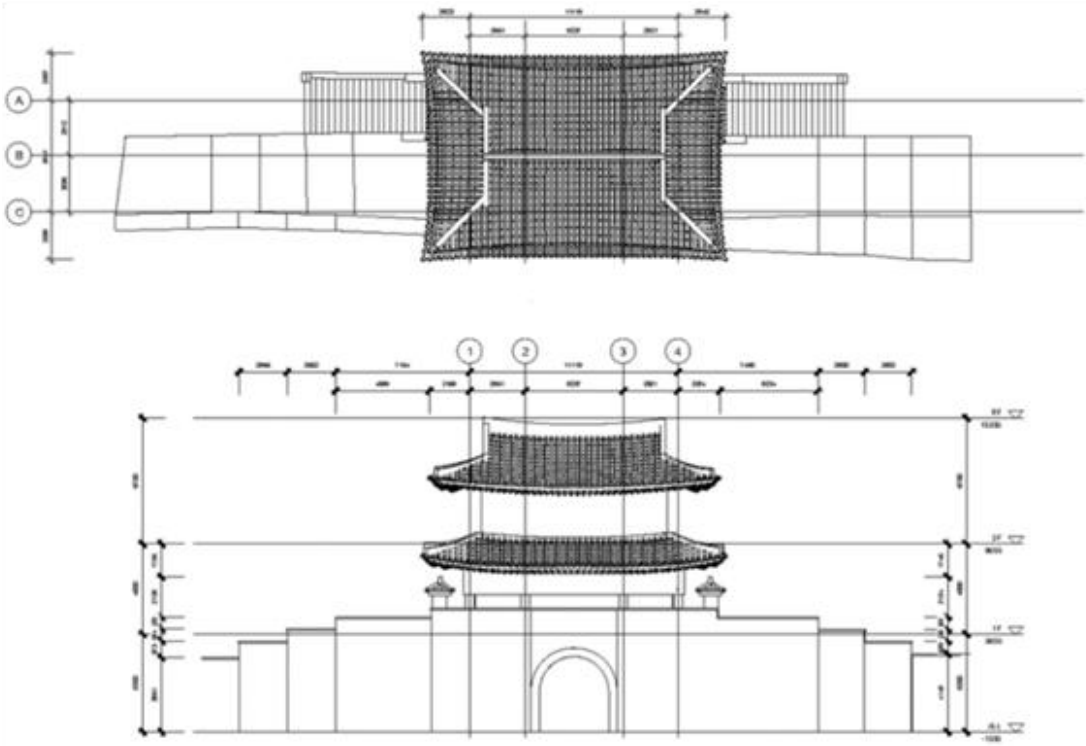

Figure 6. Two-dimensional plane map (above) and front view map (below) for the Gongbukmum

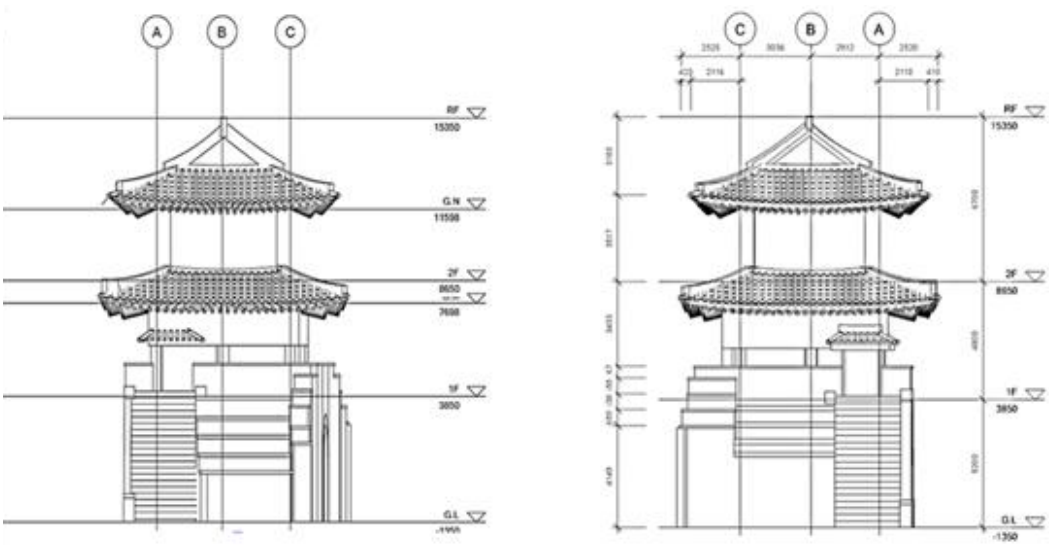

Figure 7. Two-dimensional left side view map (left) and right side view map (right) for the Gongbukmum

drawings by floor could be prepared in the form of dwg extensions. Fig. 6 and 7 show major drawings of Gongbukmun prepared through the reverse engineering technique.

4. Qualification check for 3D-Gongbukmun as a digital heritage

In the present study,point cloud datawere obtained from Jinju Castle, Gongbukmun through 3D Scanning and these data were processed and matched to construct 3D-Gongbukmun, which is a 3D model. In addition, main drawing maps could be prepared through the reverse engineering technique. Therefore, the 3D-Gongbukmun made as such was analyzed to see if it has a value as a digital heritage.

The analysis was conducted by reviewing whether 3D-Gongbukmun satisfied the requirements for 'common core' as a'digital heritage' defined in the study report published in July 2010 by Heritage lottery fund(Flow & Collections Trust, 2010). The 'common core' for 'digital heritages' defined in Flow & Collections Trust(2010) is as follows.

a) The development and delivery of digital content and media (delivered online or in other platforms)
b) The creation and management of large-scale datasets
c) The creation and management of digital surrogates of physical things
d) The delivery of existing services online
e) The use of technology to enable back-office functions
f) The provision of tools for interaction, collaboration and user-generated content
g) The usage of technical tools for monitoring and evaluation
h) The arrangements for licensing and ownership of digital properties
i) The challenges of long-term digital preservation and web archiving
j) The emergence of new business models which depend on different technologies and platforms (such as image licensing).

3D-Gongbukmun, which is a 3D model of Gongbukmun developed by the Spatial Information Laboratory of Gyeongnam National University of Science and Technology was made into the form of a 3D digital file by processing large scaled point cloud data and satisfies conditions a), b), c), and i). If this 3D-Gongbukmun file is loaded on a serverthe terms ofd. and e. can be satisfied.In addition, since the Spatial Information Laboratory of Gyeongnam National University of Science and Technology is planning to register 3D design for 3D-Gongbukmun, the ownership under condition h. may be partially recognized but the issues related to the original ownership and licensing should be actively discussed as time goes on. In addition, since products can be produced through 3D printing after 3D design registration for 3D-Gongbukmun, the emergence of new business models under condition j. is assumed to be possible. Therefore, based on these analysis results, 3D-Gongbukmun is judged as being equipped with requirements as a digital heritage and the fabrication of models of 3D-Gongbukmun by combining the 3D printing technology is to be left as a future research task.

5. Conclusions

In the present study, a 3D digital model of an existing cultural property was made using thereverse engineering technology and whether the model satisfied requirements as a digital heritage was reviewed. The present study was intended to fabricate digital cultural heritages for existing culturalproperties using the reverse engineering technology and obtain two-dimensional drawingssuch as front views, ground plans, and side views etc.Jinju Castle, Gongbukmun was selected as a study subject and 3D-Gongbukmun, which is a 3D model, could be constructed by scanning the subject utilizing a 3D scanner and processing the point cloud data thereafter.In addition, although there was no drawing of Gongbukmun, two-dimensional drawings of it could be successfully prepared through the 3D-Gongbukmun model.In addition, the fact that the3D-Gongbukmun model sufficiently met the requirements as a digital heritage could be identified. The present study is expected to be capable of activating studies in the area of policies for the definition, reproduction, and preservation of digital heritages.

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