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3D Modeling of Both Exterior and Interior of Traditional Architectures by Terrestrial Laser Scanning at Multi-Stations*

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다중 지점 지상레이저스캐닝에 의한 전통 건축물의 내부와 외부의 3차원 모델링*

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ABSTRACT

The purpose of this research is to present about a series of processes for 3D model generation from scan data of two types of Korean styled architectures, namely, a pavilion and a house, which were acquired with the terrestrial LiDAR and evaluate a 3D surveying method to document digitally the traditional buildings, cultural properties, archeological sites, etc. Since most ancient buildings and cultural assets which require digital documentation by the terrestrial laser scanner usually need to acquire data from multi-directions. Therefore this paper suggested a process of acquiring and integrating data from mult-stations around the object. Also we presented a way for reconstructing automatically at once both the interior and exterior surfaces of buildings from laser scan data.

KEY WORDS : Terrestrial LiDAR, Laser Scanning, 3D Modeling, Digital Documentation, Traditional Architectures, Spatial Information

요 약

본 연구는 지상 라이다에 의해 획득된 두 가지 유형의 한국전통양식의 건축물에 대한 스캔 데이

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터로부터 3차원 모델을 생성하는 일련의 처리과정을 제시하고 전통건축물, 문화재, 고고학적 유적지 등을 수치적으로 기록·문서화하기 위한 3D 측량방법을 평가하는데 목적을 두었다. 지상레이저실측을 통한 수치적인 기록화를 필요로 하는 대부분의 고건축물이나 문화재 등은 모든 방향에서 데이터를 취득할 필요성이 있다. 본 논문에서는 대상물 주위의 다중 지점에서 데이터를 획득하여 통합하는 과정을 제시하였다. 또한 레이저 스캔 데이터로부터 건축물의 외부와 내부 양면을 동시에 자동적으로 재구성하는 접근법을 제시하였다.

주요어 : 지상 라이다, 레이저 스캐닝, 3차원 모델링, 수치기록화, 전통 건축물, 공간정보

Introduction

A terrestrial LiDAR equipment has the advantages that are able to obtain a great number of observations with high precision in a short time(Lee *et al.*, 2009*a*,). On the other hand, it is not so difficult to handle when surveying, but it needs lots of time and some level of skill during the processing in the office. For archaeological investigations, textured three dimensional models of archaeological sites are also useful for visualization purposes to engage the public and assist archaeologists in interpretations of past uses of space(Gonizzi *et al.*, 2013). Reverse engineering, that is, the art of reconstructing the shape includes three steps i.e. measuring real world object, converting observed data to structured point-clouds and building three dimensional model or shape.(Lee *et al.*, 2009).

On-site three dimensional scanning acquires high-density spatial image data with a great number of coordinates promptly and precisely with the camera and other measuring devices. Three dimensional data from laser scanning data are very useful because the derived geometric models are the exact/metric copy of the original object and a number of different analyzes and researches can be performed(Gonizzi *et al.* 2013). Sa *et al.*(2006) developed a fusion approach for building reconstruction from both points and images, namely, data collected by terrestrial laser scanner and close-range photogrammetry. The proposed approach was then applied to reconstructing a building model from real data sets acquired from a large existing building. Lee and Kim(2009) suggested the method of constructing and realizing the beach surface model based on data collected with a terrestrial LiDAR and GPS. Kim *et al.*(2008) extracted road geometric data, road facility and slope for three dimensional road modeling in dangerous road section using integrated multi-sensor data collected from a variety of sensors mounted in a ground vehicle borne system.

Using three dimensional precise scan data created with the terrestrial LiDAR, we can see documentations made already in the real world and get everlasting records for immediate or future use. Three dimensional laser scanning technology collects high density point data, digitizes all of three dimensional spatial information of real world objects and permits to create digital surface models that accurately express the variability of the surface. It has been used to create accurate shape without touching the object, which is the basic requirement for preservation and restoration, such as buildings, cultural properties and structures and used to extract spatial information from recorded digital data.

We intend to demonstrate the process that 3D model is generated through a series of procedures from scan data collected with the terrestrial LiDAR until the superposition procedure, as carried out for two Korean styled architectures. We tried to suggest a process of acquiring and integrating data from multi-stations around the object and present an approach to reconstruct automatically of both the interior and exterior of the architecture simultaneously from laser scan data.

Laser Scan Data Collection and 3D Modeling

1. Description of Equipment and Software

The terrestrial LiDAR equipment used for this research is the Z+F IMAGER 5010C model made by Zoller+Fröhlich co.,

FIGURE 1. 3D Laser scanner (Model: Z+F IMAGER 5010C)

TABLE 1. Specification of Z+F IMAGER 5010C

Item	Standard
Maximum distance	187.3m
Minimum distance	0.3m
Resolution range	0.1㎜
Collection speed	〈 500,000pxl/s
Accuracy(Linearity error)	≤1㎜
Vertical field of view	320 deg.
Horizontal field of view	360 deg.
Camera	HDR camera

as presented in Figure 1 and Table 1. It collects color panoramic images with not only high-quality and great precision but range and spherical field of view since a HDR camera is built in it(Fröhlich *et al.* 2009).

The terrestrial LiDAR measures and registers relative coordinates which are transferred to a Notebook PC. Z+F Laser Control is a 3D scan modeling software which was used for post-processing of laser scan data in this research(Lee *et al.*, 2017).

2. Registration and Georeferencing of Point Cloud Data

To generate the three dimensional model of an object, the laser scanner need to scan in several different positions. Multiple point clouds collected from different positions require a registration operation to constitute the entire three dimensional model. The most common way is to place some targets that can be recognized by the terrestrial LiDAR before scanning. The scanner can mark the targets as specific points and different point clouds can be registered with the targets they

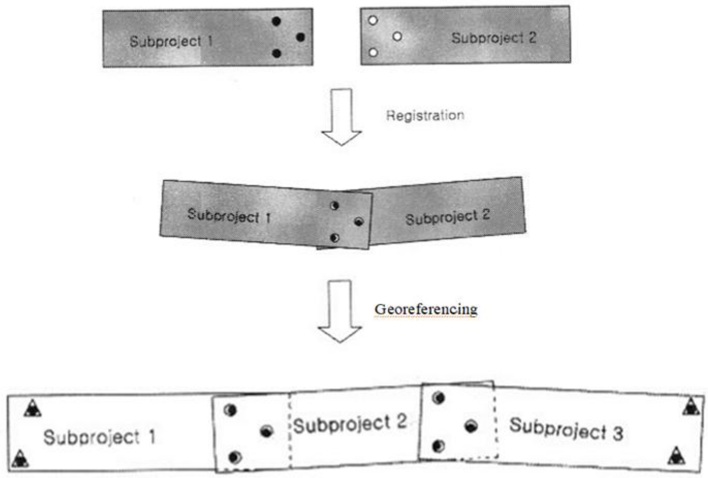

FIGURE 2. The diagram of registration and georeferencing of continuous scan data

share(Wang *et al*, 2014).

The scanning data which were aligned in the same coordinate system by registration are transformed into real coordinates through combining with ground control points by the georeferencing as shown in Figure 2(Lee *et al.*, 2009*b*).

3. Project Ⅰ(Pavilion)

Most of the pavilions are structures built for the purpose of rest in a beautiful place. The Korean styled pavilion which was selected as a research object is an octagonal tablet with about 5 meters in diameter and about 7 meters in height. It is a structure with eight pillars and an open inside without a railing. Laser scanning data were acquired in order one by one at five stations as showd in Figure 3 and Figure 4. In Figure 4, St.5 is the station for scanning the ceiling of the pavilion. Table 2 presents the X,Y,Z coordinates of eight reference points measured by a total station. These coordinates are not absolute coordinates, but assuming that the X,Y,Z coordinates of the telescope center, that is, the machine center of the total station installed at any one point on the site according to the site situation, are (5000.000m, 5000.000m, 100.000m), the positions of the eight reference points attached to the eight columns of the pavilion were observed as relative coordinates.

The weight of data was reduced by one-third original data through thefiltration

TABLE 2. The coordinates of reference points

No.	X(m)	Y(m)	Z(m)
101	5000.000	5003.509	100.268
102	4997.485	5002.520	99.634
103	4996.356	5000.056	99.998
104	4997.309	4997.516	100.219
105	4999.767	4996.412	99.717
106	5002.331	4997.350	99.006
107	5003.436	4999.792	99.662
108	5002.525	5002.340	98.803

FIGURE 3. Data acquisition scene for the pavilian

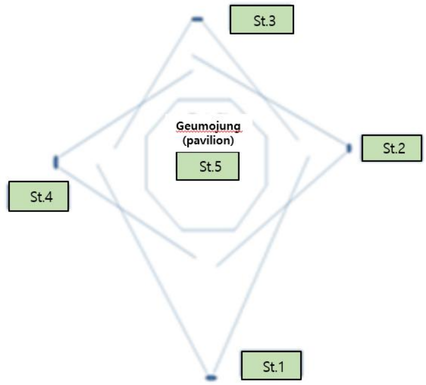

FIGURE 4. Five stations of terrestrial laser scanner

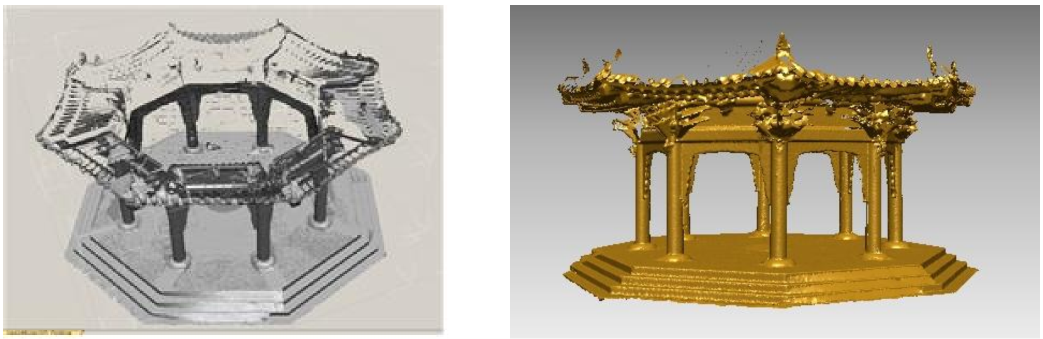

FIGURE 5. 3D model of the pavilion

process which remove needless noise data and software searches and deletes automatically 7.4mm of optimuml interval between adjacent points. Then, after running sequentially the polygon processing, the surface processing, the merge processing of shells and the error correction, the three dimensional model, as presented in Figure 5, was finally generated.

4. Project Ⅱ (Korean Style House)

A traditional Korean house called hanok was chosen as other experimental object. A total of ten laser scanning stations were placed around the object so that the surface of the object was overlapped and covered as shown in Figure 6. As in Project Ⅰ, the coordinates of twenty reference points applied in this experiment were also assigned as arbitrary coordinates to one point of the total station sequentially installed at various points in the field according to the site situation, and the positions of the reference points were observed as relative coordinates based on this. St.1 to St.9 were placed for overlaping and covering the

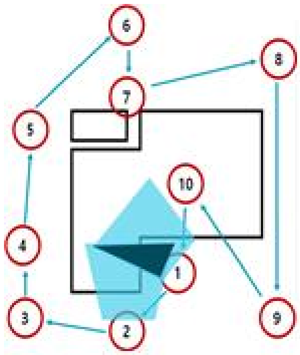

FIGURE 6. Ten laser scanning stations

outside of the house and St.10 was for overlaping and covering its inside. Especially when placing the positions of St.1 and St.10, it was necessary to check in advance the overlapping scan areas that could be covered in common at both stations.

The Z+F Laser Control program was used to conduct post processing. The laser scan data was opened by executing the Z+F Laser Control program provided by Zollar+Fröhlich, and the shooting order of 10 points was designated as shown in Figure 6. In order to process the laser scan data, the ten scan data were cleaned and aligned due to incompatibility of data format. After complete cleaning and alignment were conducted, the registered point clouds were converted into a mesh and the holes automatically filled and then finally 3D textured model was created(Lee *et al.*, 2017).

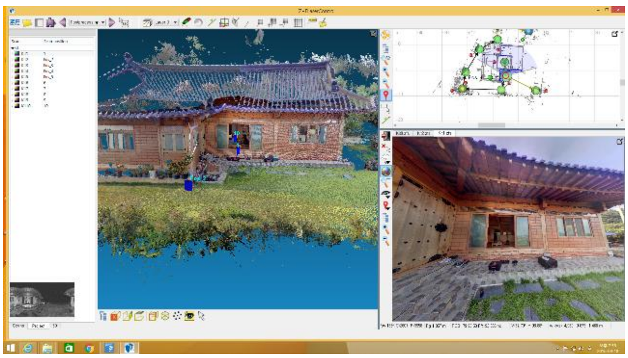

FIGURE 7. 3D model created based on the scan data of St.1

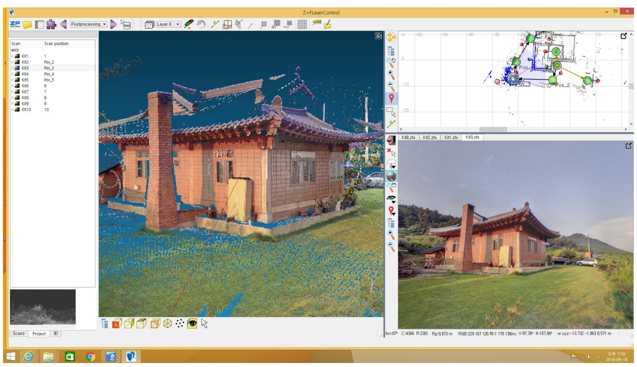

FIGURE 8. 3D model created based on the scan data of St.3

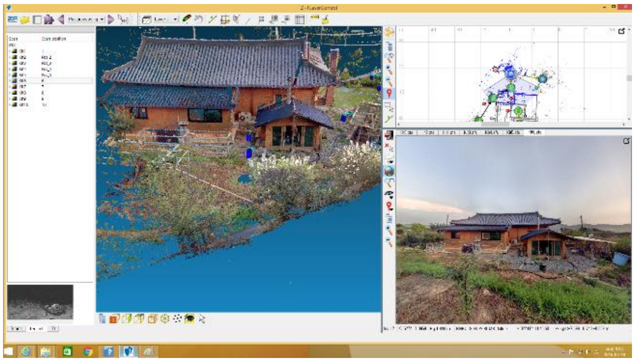

FIGURE 9. 3D model created based on the scan data of St.6

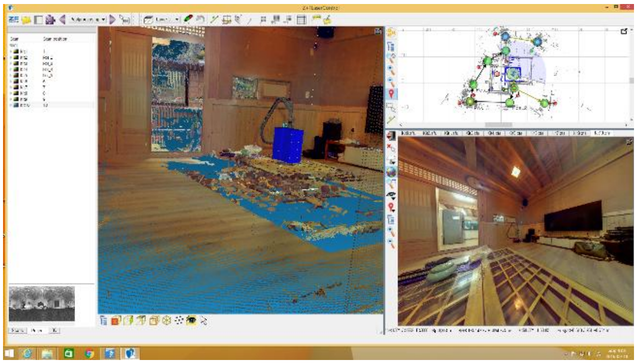

FIGURE 10. 3D model of house inside created based on the scan data of St.10

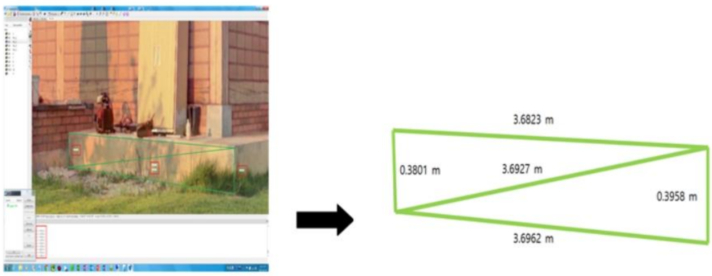

FIGURE 11. Measurement of point-to-point distance from 3D model

Through the process of data reduction and image matching through noise removal, 3D modeling was carried out. Figure 7, Figure 8 and Figure 9 show three dimensional textured models of the exterior surface of the house which were created based on the scan data of St.1, St.3 and St.6, respectively. On the other side, Figure 10 shows the three dimensional textured model of the interior surface of the house which was created based on the scan data of St.10.

Subsequently the point-to-point distance, cross section, etc. can be extracted as shown in Figure 11.

Concluding Remarks

For two types of Korean-style buildings, namely, a pavilion and a hanok, a series of processes from acquisition of terrestrial laser scan data to generation of 3D models are presented. Since most ancient buildings and cultural assets usually need to acquire data from multi-directions, this study presented a process of acquiring and integrating data from mult-stations around the object. In addition, we presented a way to reconstruct at once both the exterior and interior surfaces of buildings with relatively complex shapes based on the scan data acquired by a terrestrial LiDAR.

Since digital data rather than simple images are generally needed in order to obtain spatial information on cultural heritages, ancient architectures, etc. and record for its preservation, accurate and perfect three dimensional shape data should be created by utilizing the concept of reverse engineering technology.

These kinds of 3D data will be increasingly utilized as the source not only to restore damaged parts of cultural assets, old architectures, monuments, etc. but also to extract data for structural monitoring of them. KAGIS

REFERENCES

Arayici, Y. 2007. An approach for real world data modelling with the 3D terrestrial LiDAR for built environment. Automation in Construction 16(6):816-829.

Fröhlich, C. and M. Mettenleiter. Terrestrial laser scanning - New perspectives in 3D surveying. International Archives of Photogrammetry, Remote Sensing, Spatial Information Science Vol. XXXVI-8/W2.

Gonizzi B.S., F. Remondino and D. Visintini. 2013. 3D surveying and modeling of archaeological sites - Some critical issues -. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences Volume II-5/W1. 2013. XXIV International CIPA Symposium, 2-6 September 2013, Strasbourg, France, pp.145-150.

Han, S.H., Y.S. Bae and S.H. Bae. 2006. Application analysis of digital photogrammetry and optical scanning technique for cultural heritages restoration. Journal of the Society of Korea Civil Engineers 26(5):869-876 (한승희, 배연성, 배상호, 2006. 문화재 원형복원을 위한 수치사진측량과 광학스캐닝기법의 응용분석. 대한토목학회논문집 26(5D):869-876).

Jeong, C.D., J.M. Oh and S.Y. Kim. 2010. Accuracy analysis of building outline extracted from terrestrial laser scanner data, Proceeding of the Korean Society for Geo-Spatial Information Syatem. pp.11-18 (정철두, 오종민, 김승용. 2010. 지상라이다데이터에서 추출한 건물외곽선의 정확도 분석. 대한공간정보학회 학술발표논문 초록집. 제1권 11-18쪽).

Kim, M.G. and J.G. Sung. 2008. Extracting three-dimensional geometric information of roads from integrated multi-sensor data using ground vehicle borne system. Journal of the Korean Association of Geographic Information Studie 11(3):67-78 (김문기, 성정곤. 2008. 지상 이동체 기반

의 다중 센서 통합 데이터를 활용한 도로의 3차원 기하정보 추출에 관한 연구. 한국지리정보학회지 11(3):67-78).

Lee, H.S. and I.H. Kim. 2009a. Data acquisition using terrestrial laser scanner and RTK-GPS for implementation of beach model. Journal of the Korean Association of Geographic Information Studie 12(1):54- 63 (이형석, 김인호. 2009. 해빈 모형 구현을 위한 지상용 레이저 스캐너와 RTK-GPS의 자료 획득. 한국지리정보학회지 12(1):54-63).

Lee, J.D., K.J. Bhang and W. Schuhr. 2017. 3D textured modelling of both exterior and interior of Korean styled architectures. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W5. pp.439-442. 26th International CIPA Symposium 2017, 28 August-01 September 2017, Ottawa, Canada.

Lee, J.D., S,H. Han and J.B. Lee, 2009b. Utilizing 3D laser scanning technology for remodeling work of building inside. International Journal of Contents 5(3):19-23.

Sa, S.J., I.P. Lee, Y.S. Choi, and Y.j. Oh. 2004. 3D precision building modeling based on fusion of terrestrial LiDAR and digital close-range photogrammetry. Proceeding of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography (Fall Conference), pp.529-534 (사석재, 이임평, 최윤수, 오의종. 2004. 지상라이다와 디지털지상사진측량을 융합한 건축물의 3차원 정밀모델링. 한국측량학회 2004년 추계학술발표 논문 초록집. 529-534쪽).

Sohn, H.W., B.Y. Yun, D.I. Park and K.W. Pyo. 2006. 3D shape embodiment of dam using the 3D laser scanning system. Journal of Korean Geophysical Society 9(4):377-386 (손호웅, 윤부열, 박동일, 표기원. 2006. 3차원 레이저 스캐닝 시스템을 이용한 댐체의 3차원 형상구현. 지구물리, 대한지구물리학회 9(4):377-386).

Wang, W., W. Zhao, L. Huang, V. Vimarlund and Z. Wang. 2014. Applications of terrestrial laser scanning for tunnels. Journal of Traffic and Transportation Engineering(English Edition) Volume 1, Issue 5, October 2014, pp.325-337.

Laser Design. 2021. Receiving Parts and Providing 3D Scanning Services Today. https://www.laserdesign.com/3d-scanning-building-facilities. (Accessed November 15, 2021).