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Research Article

Monitoring Method Analysis For Effective Measure Of Wooden Architectural Heritage

L. Ha Na[1], A. Dai Whan[2], K. Hwan Chol[3], Y. Hyun Woo[4], K. Dong Yeol[1]

[1] National Research Institute of Cultural Heritage
[2] Chungbuk National University
[3] Sunmoon University
[4] Myungji University

* Corresponding author, e-mail: (leehana0917@naver.com)

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Abstract.

Keywords: Wooden architecture, Cultural Heritage, Displacement, Monitoring method

Introduction:
Methods for monitoring cultural heritages are getting more efficient and scientific with the development of technology and equipment. Thus, the monitoring methods currently experienced in Korea need to be examined from various aspects. In this study, monitoring method by 3D scan are compared with the method using total station and automatic measurement.

Developments:
Among the East Asian wooden buildings, which are climate-sensitive such as change of temperature and humidity, the Geugnakbojeon of Muwi-sa Temple in Gangjin and the Jongmyo Jeongjeon in Seoul had been monitored. The advantage and disadvantage of each monitoring method were investigated by comparing the displacement measuring method and by analyzing the measurement cycle. Through this process, we propose an efficient displacement measuring method and a cycle with three of each measuring instruments.

Remarks and Conclusion:
Wooden cultural heritage should be monitored by using appropriate equipments depending on the importance of building and need for identifying periodic displacement. In this study, measurement trends of 3D scan and total station are similar, but 3D scan data analysis resuls in matching error can be occured. Follow-up research is necessary to overcome the limit to suggest a specific measurement since the period of this study was too brief and objects were limited into few buildings.

1 INTRODUCTION

National Research Institute of Cultural Heritage has selected 56 samples for monitoring which are all popular and symbolic among National treasures and treasures in South Korea.These sites require special management because of damage and aging [2]. Among them, the wooden cultural heritages show historical characteristics in furniture and roof types according to the age of the building and even hint at the environment of the time. However, they are vulnerable to fire due to the nature of the material and structural problems arising from some members. These fires are likely to spread to the entire building because the members are intertwined.

Although the measurements and recording of cultural heritages using 3D scans are being promoted to research and record cultural assets, studies on the feasibility of using 3D scan data for monitoring are lacking. Few attempts have been made to use 3D scan data for monitoring, and research on the feasibility of using 3D scan data is still insufficient. In this study, therefore, 3D scanning was compared with existing monitoring methods to derive the advantages and disadvantages of 3D scanning and to verify the possibility of future developments.

2 MONITORING METHOD

2.1 Geugnakbojeon of Muwi-sa Temple in Gangjin

2.1.1. Monitoring model

Kangjin Muwi-sa is a temple in Mount Wolchulsan at 1174, Wolha-ri, Seongjeon-myeon, Gangjin-gun, Jeollanam-do, Republic of Korea. It was founded by Great Monk Wonhyo during the Silla Dynasty and has been rebuilt several times. Geugnakbojeon, which was selected as a monitoring model, was built in 1430 with a floor plan of 3-kans in front and 3 kans on the side. The single-floor structure is a jusimpo-style gable-roofed building with double eaves [3].

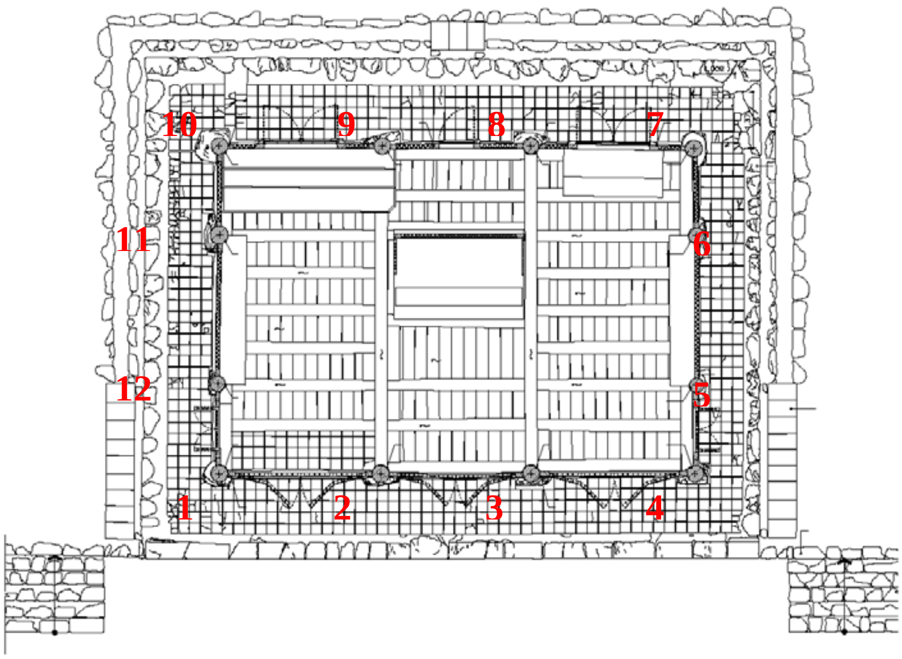


Figure 1 Measuring position

2.1.2. Monitoring method

In this study, we installed permanent boundary stones as reference points for displacement measurement; a total of 92 target points were considered: 23 in the front, 23 in the back, 23 on the right side, and 23 on the left side around the pillars and changbangs. To analyze the results, pillar numbers were assigned to them based on the southwest pillar as shown in [Figure 1].

3D scan was performed using Focus 3D × 330 from FARO. The research sequence was as follows: Install reference points → Install targets for displacement measurement reference points → 3D scan (first: all objects) → 3D scan (2nd–6th: displacement measurements) → Data post-processing → Comparison and analysis of displacement data(Table.1).

Table 1: 3D scan plan (Geugnakbojeon of Muwi-sa Temple in Gangjin)

Division	Date	Description
1st 3D scan	2016.08.31	All objects and surrounding environment
2nd 3D scan	2016.09.01	Displacement measurement part (pillar, changbang)
3rd 3D scan	2016.10.25	Displacement measurement part (pillar, changbang)
4th 3D scan	2016.10.26	Displacement measurement part (pillar, changbang)
5th 3D scan	2016.11.22	Displacement measurement part (pillar, changbang)
6th 3D scan	2016.11.23	Displacement measurement part (pillar, changbang)

The total station displacement was measured using FlexLine TS06 plus from Leica. The research sequence was as follows: Install reference points → Install reflectors for displacement measurement reference points →Total station measurement (first: displacement measurement part)→Total station measurement (2nd–6th: displacement measurement part)→Data backup (Excel and CAD interface) → Comparison and analysis of displacement data(Table.2).

Table 2: Total station plan (Geugnakbojeon of Muwi-sa Temple in Gangjin)

Division	Date	Description
1st total station	2016.09.01	All objects and surrounding environment
2nd total station	2016.10.25	Displacement measurement part (pillar, changbang)
3rd total station	2016.11.22	Displacement measurement part (pillar, changbang)

A two-axis inclinometer was installed to measure the displacement with an automatic measuring instrument, and the displacement measurement data was created using a data building program and the general-purpose application Excel. The research sequence was as follows: Install the measuring instrument and data logger → Acquire data (automatic measurement) → Compare and analyze displacement data(Table.3).

Table 3: Measuring sensor regularly plan (Geugnakbojeon of Muwi-sa Temple in Gangjin)

Division	Date	Description
Install an automatic measuring instrument	2016.10.14	Install a 2-axis inclinometer Set the data logger
Automatic measurement	2016.10.14 to 2016.11.30	Perform automatic measurement

2.2 Jongmyo Jeongjeon in Seoul

2.2.1 Monitoring model

Jongmyo Jeongjeon is a building for enshrining ancestral tablets of the kings of the Joseon Dynasty. Located at 157, Jong-ro, Jongno-gu, Seoul, Republic of Korea, it is the longest single building in South Korea. It has single eaves and a gable-roofed style with the shape of the Chinese character for human being (人) (Figure.2) [4].

Figure 2 Jongmyo Jeongjeon in Seoul

2.2.2 Monitoring method

In this study, the total displacement of the object was measured through a reference without targets installed for displacement measurement in the Jongmyo Jeongjeon, The 3D scan research method was the same as the one used for the Geugnakbojeon of Muwi-sa Temple in Gangjin(Table.4).

Table 4: 3D scan plan (Jongmyo Jeongjeon)

Division	Date	Description
1st 3D scan	2016.08.30	All objects and surrounding environment
2nd 3D scan	2016.09.06	Displacement measurement part
3rd 3D scan	2016.09.20	Displacement measurement part
4th 3D scan	2016.10.04	Displacement measurement part
5th 3D scan	2016.10.18	Displacement measurement part
6th 3D scan	2016.11.01	Displacement measurement part
7th 3D scan	2016.11.15	Displacement measurement part
8th 3D scan	2016.11.23	Displacement measurement part

3 MONITORING ANALYSIS

3.1 Analysis of results according to displacement measuring instrument employed

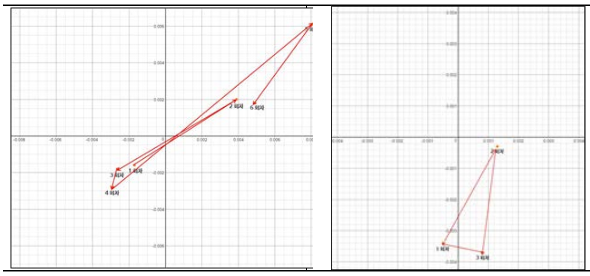
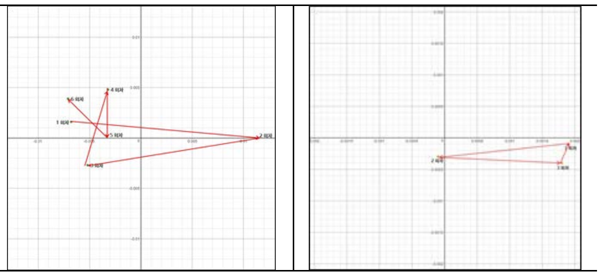
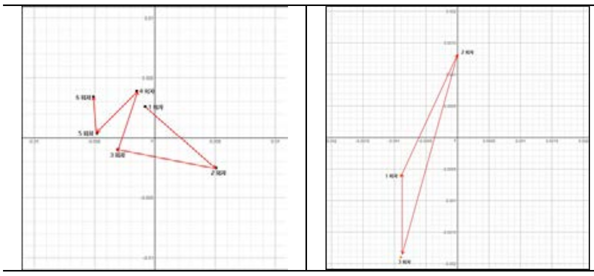
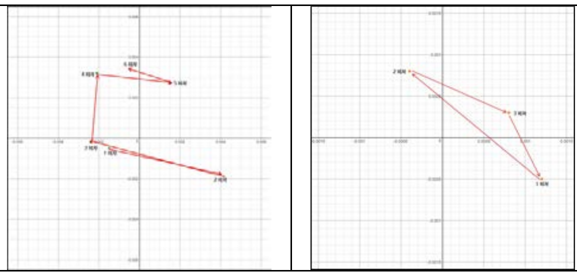
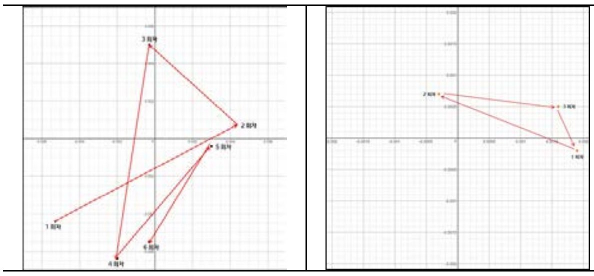
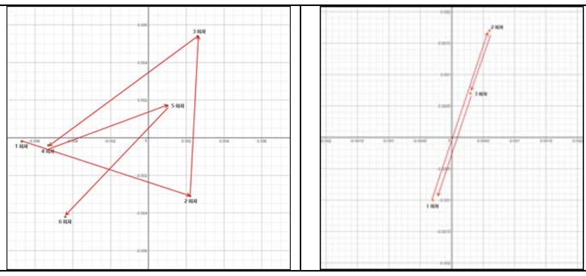
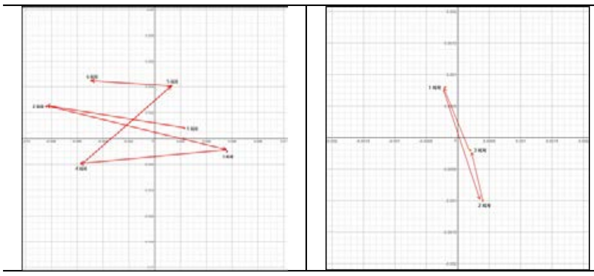
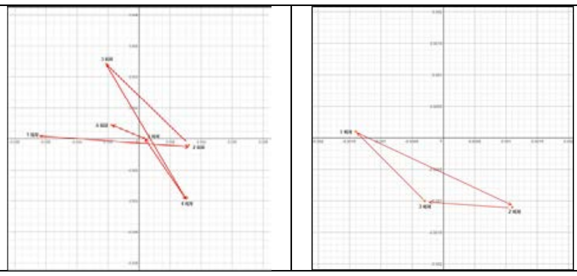
[Table 5] shows the result obtained by measuring the 12 pillars shown in [Figure 1] 8times. The left two graph shows the movement of 3D scan, and the right two graph shows the movement of the total station.

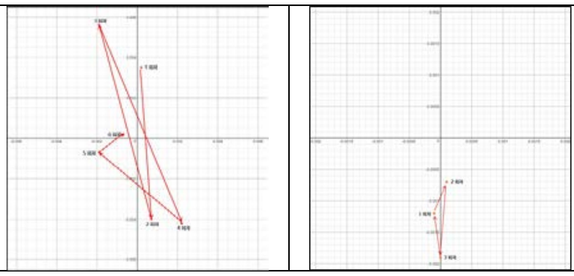
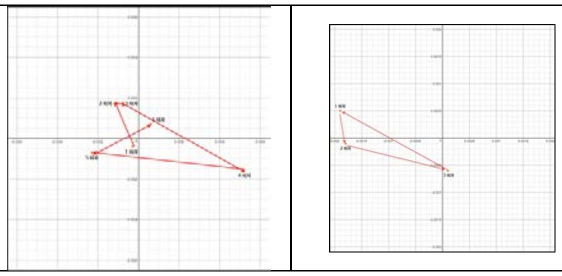
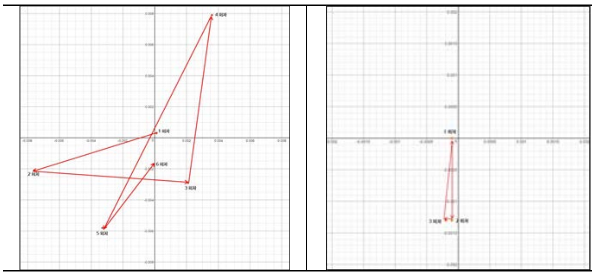
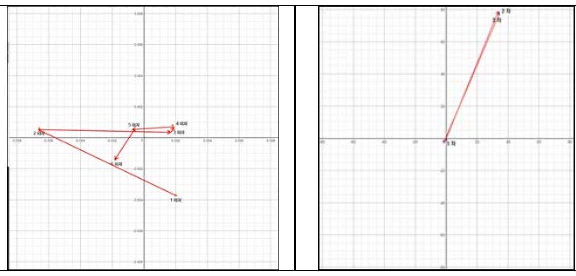
The analysis of the results for the displacement measurements of the 3D scan confirmed that each pillar showed different behaviors although the directions were similar. To examine the displacement behaviors in the southwest–northeast direction, pillars 1 and 6 showed displacement behaviors in round trip, pillars 3 and 5 showed displacement behaviors in the southwest → northeast direction, and pillar 6 showed displacement behaviors in the northeast → southwest direction. For the southeast–northwest displacement behaviors, pillar 4 showed displacement behaviors in the southeast → northwest direction and pillars 8 and 9 showed displacement behaviors in the northwest → southeast direction. Thus, pillars displacement behaviors appeared in opposite directions.

In the case of total station, pillars 6 and 11 showed displacement behaviors in the southwest ↔ northeast directions, and pillars 1, 3, and 9 showed displacement behaviors in the southwest → northeast direction. Pillar 12 showed displacement behaviors in the northeast → southwest direction, which is opposite to the direction the displacement behaviors of pillars 1, 3, and 9. Furthermore, pillars 7 and 8 showed displacement behaviors in the southeast ↔ northwest directions and pillar 4 showed displacement behaviors in the southeast → northwest direction(Table.5).

For automatic measurement, two 2-axis inclinometers were installed on pillars 7 and 10 to measure the displacement values. As a result, the minimum and maximum displacements of TL_X in the TL_XY values of pillar 7 were -0.002mm and 0.038mm, respectively, which were both measured on October 18. The minimum and maximum displacements of TL_Y were -0.026mm on October 15 and 0.012mm on November 1, respectively. The minimum and maximum displacements of TR_X of pillar 9 were -0.002mm on October 14 and 0.027mm on October 15, respectively. The minimum and maximum displacements of TR_Y were -0.026mm on October 18 and 0.012mm on November 1, respectively. Many of the minimum and maximum displacements occurred on October 18, and the cause for this should be investigated to determine the existence of any environmental factors.

Table 5: 1st–8th displacements of pillar inclination (3D scan, total station)

	
1 (Left: 3D scan, Right: Total station)	2 (Left: 3D scan, Right: Total station)
	
3 (Left: 3D scan, Right: Total station)	4 (Left: 3D scan, Right: Total station)
	
5 (Left: 3D scan, Right: Total station)	6 (Left: 3D scan, Right: Total station)
	
7 (Left: 3D scan, Right: Total station)	8 (Left: 3D scan, Right: Total station)

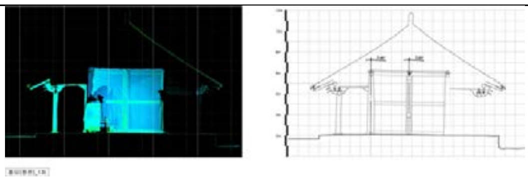
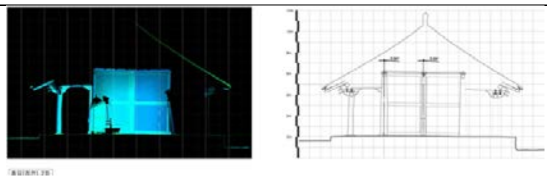
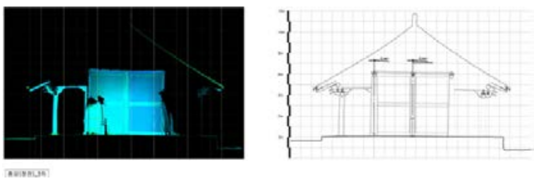
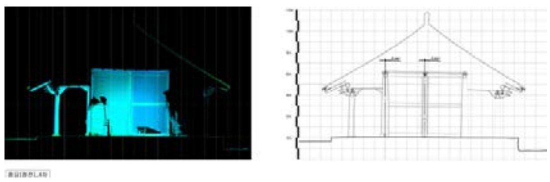
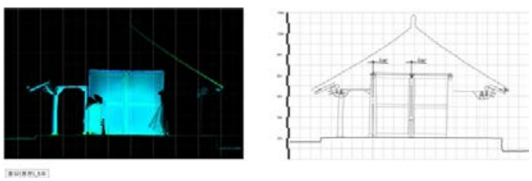
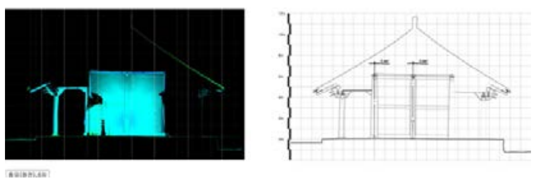
	
9 (Left: 3D scan, Right: Total station)	10 (Left: 3D scan, Right: Total station)
	
11 (Left: 3D scan, Right: Total station)	12 (Left: 3D scan, Right: Total station)

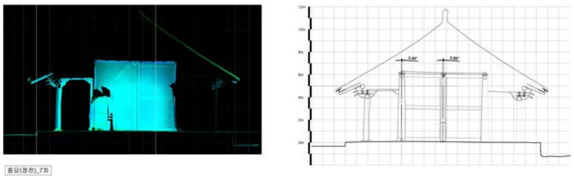
3.2 Displacement analysis using longitudinal section

[Table 6] shows the results obtained by scanning cross section of Jongmyo Jeongjeon 8times.

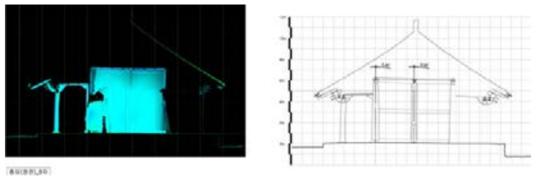
As a result of the first 3D scan of Jongmyo Jeongjeon, the measurement value of the pillar with the largest displacement was 0.46° in the front and 0.6° in the center. A comparison between the pillar inclinations based on these values showed no overall difference. In particular, the front pillar showed a displacement of 0.4mm in the 1st and 2nd measurements and -0.4mm in the 2nd and 3rd measurements; however, the 3rd–8th measurement values were identical to the value of the first measurement. In the case of the center pillar, the displacement values ranged from -0.07mm to 0.9mm for the 2nd to 8th measurements(Table.6).

Table 6 1st–8th displacements of pillar inclination

	
1st	2nd
	
3rd	4th
	
5th	6th



7th



8th

3.3 Comprehensive analysis

In the case of automatic measurement, there was a limitation in analyzing the two data values and the result values, owing to a short research period. However, the pillar displacements of 3D scan and total station at pillars 5 and 9 showed behaviors in opposite directions. Pillars 2, 11, and 12 showed different types of displacement behaviors, but revealed similar trends in some iterations. The displacement behaviors of pillars 1, 3, 4, 6, 7, 8, and 10 appeared relatively similar in the southwest to northeast direction.

3D scan enables multilateral examination of the shape information using 3D data, which is very useful. Total station allows selective measurements of the necessary parts. Furthermore, automatic measurement offers the advantage of allowing constant measurement and the setting of a measurement period according to the purpose. However, total station provides limited numerical information. Furthermore, 3D scan takes more time to acquire experts and data. In the case of automatic measurement, a thorough review and preparation are required since the installed instrument is different depending on the data type to be obtained. Both methods have the disadvantage of high initial cost.

4 CONCLUSION

The displacements of wooden cultural heritages were measured using 3D scan, total station, and automatic measurement to obtain an efficient displacement measurement. Furthermore, a reasonable measurement period and a displacement measurement method were proposed by comparing the advantages and disadvantages of each measuring instrument.

Displacement Measurement results by 3D scanning and total station indicated 7 out of 12 pillars in Geugnakbojeon of Muwi-sa Temple in Gangjin has similar directional movements. Jongmyo Jeongjeon with 3D scan method had almost no difference on the 1st, 2nd, 5th and 6th measurement, but had 9.8mm of difference on the 4th and 7th order. Surely, matching error point must be concerned enough.

Since the period of study had been too short, with the periodic limit, for suggesting the compatible way of displacement measurement and analysis period, follow-up study to should be carried out especially consider efficient term of study, the advantage and disadvantage of additional part and equipment including participants, expenses concretely.

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