Application of 3D laser scanning technology for preservation and monitoring of Thai pagoda: A case study of Wat Krachee Ayutthaya

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Abstract. 3D laser scanning technology is one of the current technologies for developing a sustainable and smart city. This technology is applied to obtain the three-dimensional information of building in digital format. To preserve the historic structure, the current structural information is required for structural assessment, monitoring, and conservation planning. The data obtained by the 3D laser scanner is normally used to generate the three-dimensional point cloud data of the building surface. The high-density point cloud data represented the dimension, shape, and size of the building in the current state can be acquired in more accurate and faster than another technique. This paper aims to present the application of 3D laser scanning technology for preservation and monitoring of heritage pagoda in Thailand. The pagoda of Wat Krachee located in Ayutthaya province of Thailand was selected as a case study. The results obtained in this study are a part of Wat Krachee conservation project, which is led by UNESCO Bangkok and the Fine Arts Department, Thailand. One of the challenges in Wat Krachee project is how to preserve the masonry pagoda with two intertwined trees growing inside and become a part of pagoda structure. The terrestrial 3D laser scanner was applied to develop the digital data documentation and 3D model of pagoda in the current state. The 3D survey work has been started since February 2018. The analysis of data obtained in February 2018, Mar 2018, July 2018, and July 2019 was carried out. The significant dimensions and deformation of pagoda are monitored. According to the results, it is found that the 3D laser scanning technology is very effective for assessment and monitoring. The 3D point cloud model obtained in this study can be used to develop the assume original model of the Wat Krachee pagoda, which is the inverted bell-shape with a square base.

1. Introduction
Wat Krachee is a small temple located in the area of Ayutthaya historical park. In this temple, there is an outstanding pagoda, which has two intertwined trees growing inside as shown in Figure 1. According to the material deterioration and the growing of the intertwined trees, the stability of pagoda has to be assessed and monitored intensely. Consequently, Wat Krachee conservation project was started since February 2018 by cooperation with UNESCO Bangkok and the Fine Arts Department of Thailand. The shape of pagoda is an inverted bell shape and the archaeological assumption indicate that this pagoda should be constructed in the middle period of Ayutthaya [1-3]. However, the precise archaeological
records are rarely found. In order to preserve the pagoda, the current structural information of the pagoda is very important. The 3D laser scanning technology is a current survey technique that can be collected the massive point cloud data with more accurate and faster than another technique [4-5]. Consequently, Wat Krachee conservation project applied 3D laser scanning technology for collecting the current data of the shape and dimension and also in long time monitoring. The data obtained by the 3D laser scanner is used to generate the three-dimensional point cloud data of the pagoda. This paper presents a monitoring procedure and the monitoring results of the Thai pagoda in an approximately one-year period, which have never been reported elsewhere. The inclination angle and some significant dimensions are presented in the following sections.

![Figure 1. Images of Wat Krachee pagoda](image1)

(a) 12 Feb 2018, (b) 6 Mar 2018, (c) 19 Jul 2018, (d) 27 Aug 2019

![Figure 2. Fieldwork and example of survey marker.](image2)

2. Fieldwork
The FARO Focus3D X330 was applied for collecting the point cloud data of this project. The 3D survey work was done in February 2018, March 2018, July 2018, and July 2019. The picture of pagoda in each time period is shown in figure 1. In this project, four survey markers were constructed in site for a sake of monitoring as shown in figure 2. The coordinates of the markers are listed in table 1.

| Survey markers | x (East) | y (North) | z (Up)   |
|----------------|---------|-----------|---------|
| 01             | 18.7577 | 3.1226    | 63.6729 |
| 02             | 3.4235  | 3.0561    | 63.6733 |
| 03             | -0.8137 | -5.3113   | 63.6991 |
| 04             | -0.3457 | -17.2685  | 63.6748 |
3. Data Processing and Analysis
The process to combine the overlapping point cloud from each scan data is known as a registration process. In this study, the Scene software was applied to process the scan data and develop the 3D point cloud model of Wat Krachee pagoda. The 3D point cloud models of the data collected in February 2018, March 2018, July 2018, and August 2019 are shown in Figure 3. The coordinates of each model are constrained with the control coordinates of the permanent markers. Afterward, the point cloud data was exported as the PTX files and then transfer to Polyworks software for analyzing process. The dimensions of pagoda including height, diameter in each level, inclination angle, and also the leveling of the surrounding area was carried out. Some monitoring results obtained in this study are presented in the following section.

4. Monitoring Results
The important dimensions of the pagoda (figure 4) for each monitoring time are presented as follows.

4.1 First Data on 12 Feb. 2018
The height of the pagoda is 13.5 meters leaned toward the southeast. The vertical inclination of the pagoda is 3.54 degrees as shown in figures 4 (a). The top part of pagoda was deteriorated and its remaining height is 3.80 m. The surface plaster mortar of pagoda was peeled away. The height of bell-shaped layer is 3.35 m. There is a cavity, which is a damage from human, in the northern side of pagoda with a size of 0.7 to 1.3 m as shown in figure 4 (b).

4.2 Second Data on 06 Mar. 2018
In this time period, the archeology excavation and the rehabilitation process was started. The vertical inclination is remain 3.54 degrees. According to the process of materials replacement, the diameter of the pagoda at 1.4 m from ground level was decreased from 8.83 m. to 7.87 m as shown in Table 2. However, the overall stability of the pagoda is not changed significantly.

4.3 Third Data on 19 Jul. 2018
After five months from the first survey, the vertical inclination is changed to be 3.58 degrees. In this time, the dimension of a chamber inside the pagoda was collected and measured as shown in figure 4(c). The total height of the chamber is 5.7 m with multiple layers as shown in figure 4(c). The lowest wall thickness is equal to 0.5 m located at 6 m height from the ground level in east direction as shown in figure 4 (d). The scaffold was installed for preservation works and damage inspection.
Figure 4. 3D point cloud data of WatKrachee.
(a) The inclination and the height of pagoda, (b) The hole in the northern side of pagoda,
(c) The chamber inside of the pagoda, (d) The section that shown the lowest thickness of pagoda

4.4 Fourth Data on 27 Aug. 2019
The overall dimensions of the pagoda is remain unchanged significantly. According to a number of scaffold, the inclination angle cannot be determined.

Finally, the 3D original shape of pagoda can be assumed based on the 3D scan data presented above and the other archeology data. The assumed shape of pagoda is the inverted bell-shape with a square base as shown in figure 5.
Figure 5. Show the assumed model of the pagoda at Wat Krachee (a) Assumed model in 2D, (b) Assumed model in 3D.

Table 2. Example of some monitoring results

| Measurement                              | First Data | Second Data | Third Data | Fourth Data |
|------------------------------------------|------------|-------------|------------|-------------|
| Inclination angle (degrees)              | 3.54       | 3.54        | 3.58       | -           |
| Inclination direction                    | southeast  | southeast   | southeast  | southeast   |
| Diameter at 1.4 m. from ground level (m.) | 8.83       | 7.87        | 7.87       | 7.87        |
| Cavity size (m.)                         | 0.70 – 1.30| 0.70 – 1.30 | 0.70 – 1.50| 0.70 – 1.50 |

5. Conclusions
This paper presents the application of 3D laser scanning technology for preservation and monitoring of Thai pagoda. The pagoda of Wat Krachee located in Ayutthaya province of Thailand was selected as a case study. The results obtained in this study are a part of Wat Krachee conservation project, which is led by UNESCO Bangkok and the Fine Arts Department, Thailand. The field works have been done in four periods from February 2018 to July 2019. It is found that the 3D laser scanning technology is very effective for assessment and monitoring. According to 18 months monitoring, the results show that there are not significant change in dimension and stability of Wat Krachee pagoda. The 3D point cloud model obtained in this study can be used to develop the assume original model of the Wat Krachee pagoda, which is the inverted bell-shape with a square base.

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