Fine Deformation Monitoring of Ancient Building Based on Terrestrial Laser Scanning Technologies

The Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences

liqi
Outline

• Introduce the Tower of Buddhist Incense
• Data acquisition
• Data processing
• Deformation monitoring
• Three dimensional modeling
• 3D Information Management System Study on the Preservation and Monitoring of Historic Building
As the material evidence of the ancient civilization, heritage buildings record the history of a nation’s political, economic and cultural development in a particular period.

the Tower of Buddhist Incense
Today, we take the Tower of Buddhist Incense in the Summer Palace as our research subject.

As the symbol of the Summer Palace, the Tower of Buddhist Incense, containing profound historical and cultural connotation, represents the highest achievement of traditional Chinese architectural art. The octagonal, three-storied and quadruple-eaves wood-constructed tower is built on a 20-metre-high granite platform with the Longevity Hill in the north and the Kunming Lake in the south. There’re eight solid lignumvitae column served as pillars supporting the 36.47-metre-high tower.
Due to disrepair, natural disasters, climate change and human activities, there is great danger facing many ancient buildings.

- Roof ridge animal
- glazed roof tile
- Pests damaged the wooden pillar
- Most of the paint has been scratched away
Therefore, it has become an imminent global problem that how to apply advanced technologies and methods to the documentation of the historical background and actualities of heritage buildings, which could provide sufficient and accurate data for the monitoring, preservation and restoration of ancient buildings.
Be able to directly acquire the geospatial data of an object’s surfaces, laser scanning technology has been widely used to build the high-precision three dimensional models in the preservation of ancient buildings.
According to the capabilities of different Laser Scanning devices, we choose Z+F IMAGER 5006i, to acquire high resolution point clouds at close range (less than 79 meters) by its phase ranging methods. Meanwhile, we also use Leica ScanStation C10 to obtain long-range and high-accuracy data by its pulse ranging methods. With up to 300-meter range, data of the whole tower can be collected with high precision by this scanner. These two instruments complement each other, with both of which the integrity and accuracy of the tower’s 3D geospatial data can be insured. In this project, the average measurement error of single point is about 2 millimetres.
Registration of Terrestrial Scan Data

In the process of data acquisition, due to complicated objects overlapping caused by observing from different points of view and the geometric characteristics of the object itself, it’s hard to obtain complete information of a certain target just from one scan station.
Registration of Terrestrial Scan Data

It usually requires multiple scans from different stations. As the point clouds acquired from each scan station locate in its own coordinate system, the question then arises, “how to translate all the point clouds from different scan stations to one unified coordinate system?”, which is also called Data Registration. The solution is to use the same group of artificial targets which are placed in the scene and measured from each of the overlapping scan stations, and ensure that there’re more than three common artificial targets, which are non-collinear and non-coplanar, between each two neighbouring stations.
In order to improving the registration precision, 92 scan stations were set up for data acquisition. Moreover, some more artificial targets are placed to increase redundant observations, based on which there’re still common targets between stations with one-to-two-station intervals. The registration error of point cloud data is less than 5 millimetres.

The point clouds of the first storey

Registration result of the first storey
Registration of Terrestrial Scan Data

Data capture of the second storey

Point clouds

Registration of the second storey
Registration of Terrestrial Scan Data

registration result of the three stories

registration result of the integral tower
Produce CAD drawings

The slices of point clouds we get many cross-sections in each storey, and then each cross-sections can outline structural feature of building.
The elevations of the Tower of Buddhist Incense

The sections of the Tower of Buddhist Incense
After data registration of the whole tower with high-precision, the deformation monitoring can be conducted. In order to estimate the dip and dip direction of every pillar, we get the cross-sections from the top and the bottom part of the pillar segment in each storey, and then eight cross-sections can be obtained from one integral pillar including the pillar segment inside the double eaves above the third storey.
Finally, the dip and dip direction of every pillar can be worked out by connecting the centre points of the pillar.
Based on the above results, we can get the conclusion that the tower has a slight inclination towards the southeast, and the dip angle is around 0.7 degree.
In the modern world, the Tower of Buddhist Incense has often been repaired every few years. We must record the status and history information elaborately and comprehensively. Laser scanning technologies are applied to 3D model building of the Tower of Buddhist Incense in the Summer Palace, and the detail property of the tower components can be recorded based on 3D models.
Roof ridge animal scanned by portable 3D scanners

The lion's model

Eaves scanned by Z+F laser scanners

The model of eaves
Data capture of the three storey

The fresco’s 3d model

Data capture of the xumi place

The model of the xumi place
Linear structure of the Tower of Buddhist Incense

Planar structure of the Tower of Buddhist Incense
It turns out that building the database of 3D models and picture archives helps to preserve the original data of cultural heritage, including the spatial relationship information and other important types of data. It can also contribute to the scientific, accurate and permanent protection of endangered cultural relics.
The tower has a complicated structure, so the 3d models of the tower are divided into three storeys to manage, and the same components are put in a category in single storey.

Using the mouse to click on any one component, this component property dialog pops up.
The dialog box of component maintenance information

Maintenance organization

Maintenance time

Maintenance record
The dialog box of component information management

Shooting time of photo of the tower components
Finally

Video display
汇报完毕
谢谢！