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Research Status & Development Trend of Digital Health Monitoring of Architectural Heritage

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ABSTRACT

Digital Heritage monitoring is of great importance in the preventive protection of architectural heritage. The most popular technical methods in current digital monitoring of construction heritage are including: traditional measurement technology, 3D laser scanning technology, photogrammetry technology and so on. This paper summarizes various domestic and foreign digital devices, monitoring objects and indexes by reviewing the relevant literatures on the digital health monitoring of architectural heritage. Moreover, by comparing the characteristics of several technical methods, application objects and the achievement accuracy, this paper combing the domestic and foreign application situation of the technology and the monitoring objectives appeared in typical cases, points out the characteristics of various methods and the problems that may be faced by the current construction heritage monitoring.

1. INTRODUCTION

Historical architecture is a large, intuitive, vivid history book that exists in the environment, and the architectural heritage is rich of cultural memory. In China, with the "inscription" enthusiasm, there are totally 29 cultural heritage listed on the “World Heritage List” till now, including Great Wall, Mogao Grottoes, the National Palace Museum and others.

With the development of digital technology, digital heritage around the world is growing rapidly, in the field of architectural heritage digitization, domestic scholars in ancient buildings, caves, a number of construction sites such as the content of research work has been carried out a series of digital cultural heritage protection. These different digital methods in object, characteristics, process, there are differences in achievement and accuracy, understand the characteristics of these techniques has important reference value to the architectural heritage of the next step of health monitoring development and technology integration.

This paper will focus on ways for architectural heritage and digital monitoring at home and abroad this paper makes comparative analysis of different means of monitoring objects and damage categories applicable, provide effective reference for architectural heritage and health monitoring, problems and development trend of the digital methods were put forward.

2. Architectural heritage digital health monitoring

Health monitoring of architectural heritage is similar to human health examination, through regular monitoring work, can timely find architectural heritage in some buildings such as settlement, weathering, damage and the others. The monitoring object is what we need to collect the information in monitoring work for, the contents can be divided into the health monitoring for the architectural heritage itself and the surrounding natural .There are different diseases in the monitoring objects of different building types, and the main factors that constitute the disease are different. The annual report of Chinese Cultural Heritage Monitoring in 2014 already give us a summary of the main damage for the several typical buildings：

Table 1. Monitoring object and its main damage

Monitoring object		Main damage
Geometric Monitoring	Wooden frame building	Pest,crack,deflection,uneven sedimentation
	Tower buildings	Torsion, tilt
	Inscriptions and sculptures	Cracking, surface peeling, surface dust attachment and other man-made damage
	Large-scale heritage	Rock stability, collapse, seepage, fracture, mold
Environment Monitoring	Natural environment	Surrounding vegetation, water, climate
	Social environment	Protection scope and control zone, visitor capacity

3. Digital monitoring

The digital monitoring of architectural heritage includes Traditional measurement technology, 3D laser scanning, photogrammetry and other technical means. The following will be based on these technical tools combined with the actual case study.

3.1 Convetional methods

Traditional data acquisition methods are mostly single-point access. The common technology in traditional measurement includes leveling instrument, total station and GNSS.The traditional measurement technology can be used in the building monitoring, mainly through the regular observation of the height of the fixed point elevation to get the settlement law of the building. Li Qiuying used the DINI03 digital level for 14 months occurrence sites on the soil foundation, finally obtained the cumulative subsidence quantity is 0.7mm, indicating that the site has increased slightly.

Abed used total station and GPS to assist in monitoring the deflections and cracks of the Minaret. The tower is measured in three parts as shown in figure 1.

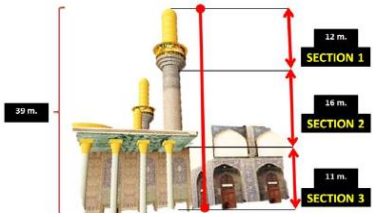

Figure 1. Minarets' measurements sections

It was found that the deflection magnitude increased between May 2014 and January 2015, these values have remained stable since January 2015.

3.2 Terrestrial laser scanning technology(TLS)

TLS is mainly used in the surface damage and structural safety monitoring.

3.2.1. Surface damage monitoring of architectural heritage

For protecting Grottoes, Yungang Grottoes Research Institute used a variety of types of terrestrial laser scanner to obtain the multi-level precision point cloud model.

Table 2. 3D laser scanner and its scanning position

Type	Accuracy	Scanning position
surphrser	0.3mm	Part of the inner walls of the grotto;
Leica ScanStation 2	4-6mm	The whole external walls
Handheld scanner	0.03mm	Details and inconvenient space

The final products is ortho-photo maps obtained by textured TIN model, which can reach millimeter or sub-millimeter. It can fully reflect all the small changes of grottoes.

Figure 2. TIN model、color point cloud、grotto damage（Lu Jiwen, 2016）

Wu Yuhua(2011) used TLS to make a comprehensive monitoring for its surface morphology of No. 9&10 Grottoes to get cracking trend of rock pillar.

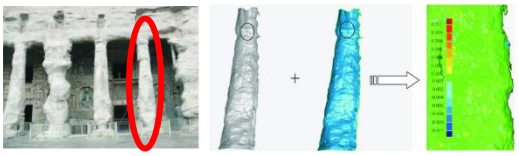

Figure 3. Yungang Grottoes 9&10 cave and two period data comparison

3.2.2. Architectural heritage deformation monitoring

On the basis of TLS point cloud for the ancient building, the overall deformation and local structural damage of the ancient building are analyzed by modeling and cutting.

Wang Yanmin(2010) analyzed the deformation of Multi-Door Chorten in Baiju Temple in 2008 and 2010 and founded the maximum change of the tower is 0.7cm and the maximum change of the five layers of the roof axis in the north-south direction is about 11.6cm.

Figure 4. Deformation analysis ,deformation analysis of the fifth story roof

Bonlali used the 3D laser scanning point cloud to the cantalovo church wall facade fitting plane as a reference face alignment point cloud data analysis in April 2011 and June 2012, the overall deformation and evolution trend from the cm level precision analysis showed that after the church facade, the temple serious deformation, the biggest difference between 3 - 4cm (Figure 5 (d)) .

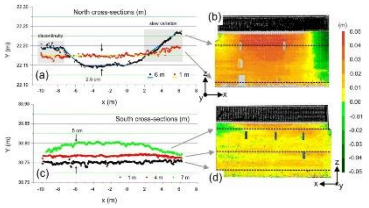

Figure 5. (a, c) for the north south elevation profile, (b, d) for the overall deformation trend

3.3 Photogrammetry technology

Low altitude and close-range photogrammetry can obtain the object shape, size, location, characteristics of heritages by 3D reconstruction from sequence images.

3.3.1. Low altitude photogrammetry

Risbøl analyzed the changes of existing environmental heritage the influence of Mecocci DEM data through the identification of ALS the changes of environment and combining with historical aerial photographs in different years the extracted and ALS of Mølen Pebble Beach surrounding natural environment are investigated.

Figure 6. 1979, 1999 aerial images, DTM generation of ALS in 2010

According to the data, the difference model of the 1968-2010 time interval is obtained, which indicates that the red area has increased since 1968, and other indicate decreasing area.

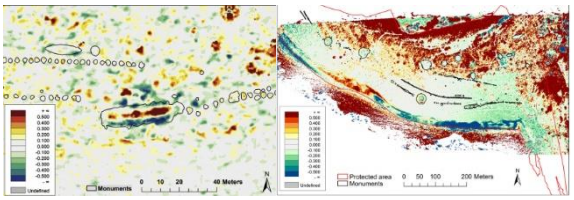

Figure 7. 1979-1999 difference model , 1968-2010 search model

Li Zhe obtained the complete surface data of Dule Temple Pagoda with UAV photogrammetry, the 3D point cloud generated with sub millimeter point density and relative measuring accuracy. According to the multi slice dissection and centroid calculation, the overall deflection data of the ancient pagoda axis eccentricity is obtained. The tower body bulging and other diseases of 3D model analysis were made on the tower(10.5m high) by Point cloud Compare.

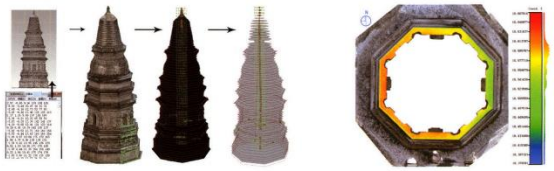

Figure 8. 3D model and sketch of horizontal cutting and Plane level pseudo color diagram

UAV has advantages in data acquisition for high-rise buildings and large ancient ruins.

3.3.2. Close-range photogrammetry

TLS can't provide enough data to construct the contours of all surface features of scanned objects, and Close-range photogrammetry compensates this defect.

Alshawabkeh(2006) extracted 3D feature of the gate (Petra's monument data from the Al-Khasneh survey), which contain clear edges and linear surface feature contours.

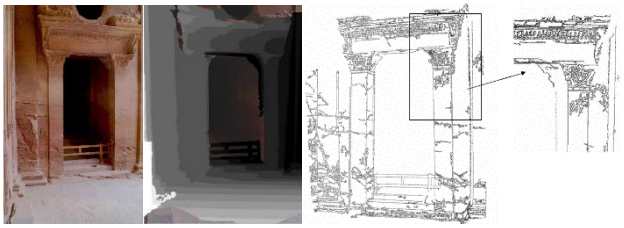

Figure 9. The left door & the distance projection image and the feature extraction

Li Yan(2010) used the digital close range photogrammetry to measure the inside and outside of the Purple bamboo Church in Tianjin, and get the elevation and plan of the building.

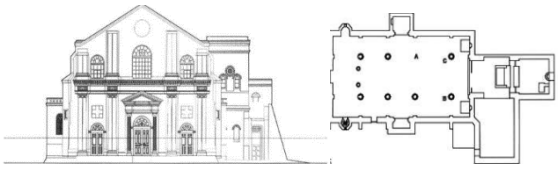

Figure 10. Purple bamboo Church elevation and plan

Photogrammetry technology is suitable for the surface features of large architectural heritage, this method is more flexible, wider scope of data collection. The introduction of photogrammetry technology makes more and more precision of architectural detail is high, the work efficiency is significantly improved.

4. Conclusion

Now the architectural heritage monitoring technology system has formed a variety of technical means to support each other, through the above analysis of literature combination of heritage protection and development trend, at present in the field of architectural heritage health monitoring there are some typical problems, specifically as follow:

1) The monitoring method and data processing of architectural heritage mainly rely on artificial, low degree of automation. Future research should focus on how to use scientific methods to improve monitoring efficiency.
2) The digital results of various types of lack of unified management, comparative analysis platform, data sharing difficult.
3) Lack of standardization heritage monitoring technology, institutional mechanism is not perfect, the lack of monitoring and warning level standard.

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