APPLICATION OF SURVEYING AND MAPPING TECHNOLOGY IN DISEASE EXTRACTION AND ANALYSIS OF STONE MONUMENTS

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ABSTRACT:

With thousands of years of glorious history and culture, China, which is the origin of Chinese civilization has also survived with a magnificent amount of stone cultural heritage. Stone monuments are one of the most important components of Chinese monuments and contain a wealth of historical information by themselves. Due to the fact that some stone monuments and stone architectural elements are often exposed to the natural environment, they are subject to physical, biological, chemical and human damage over a long period of time, which leads to the formation of various kinds of damages. Therefore, it is an important issue to extract and analysis the diseases information effectively. In this paper, we were going to examine these issues in the context of existing surveying and mapping techniques.

1. INTRODUCTION

Stone monuments are widely distributed and numerous in China. It has great historical value, artistic value, and scientific value. Only in the aspect of protecting and using the representative grotto temples, relevant guidelines have been issued from the national level. However, the theory and method of stone monuments protection are still being explored (Huang, 2006; Plevoets, Van Cleempoel, 2001). From the basic concept (Maev et al., 2020), disease types and evaluation system of stone monuments protection (Wang, Huo, 2021), protection concept (De Wever et al., 2017), procedure method and material application (Huang, 2014), they all need to be further studied to construct a complete discipline system.

The extraction and characterization of stone monument diseases is the key issue and the essential part of the protection of stone monuments (Wang, 2007). While there has been much research on the extraction of stone monument diseases domestically and internationally, a complete theory has not to be developed and generated. Preventive protection is an important direction in the development of stone monument protection, and the detection and analysis of damage are the most basic and core work of preventive protection (Wang, 2016). Nowadays, some of the techniques and methods of non-destructive testing have been put into practice in the extraction of stone monument diseases (Ji et al., 2020), as well as the initial work of summarizing and generalizing (Zhang, 2017). Nevertheless, it is still hard to meet the needs of stone monument protection regarding the current technology (Li et al., 2021).

In recent years, surveying and mapping technology has been widely used in the protection of monuments, especially in stone monuments protection projects (Rodrigues, 2015). In the relevant regulations, the mapping content and requirements of engineering geology, topography and monuments have been clarified. However, surveying and mapping technology is still a lack of further cognitive and research in the extraction and analysis of stone monument diseases. Therefore, this essay not only combines with the related characteristics of stone monument diseases, and sorts out the application advantages of typical surveying and mapping technology in the extraction and analysis of stone monument diseases, but also makes some beneficial attempts to build the stone monuments protection theory and method system.

2. ANALYSIS OF DISEASES OF STONE MONUMENTS

Recently, a few standards and specifications have been issued for stone monument diseases in China (Newell, 2008). However, due to the complex factors of stone monument diseases, the various forms of expression and the scattered distribution (Zhang et al., 2016), thus there are still some problems requiring further improvement. For example, the disease specifications of movable and immovable stone monuments have not been completely unified. It is not clear whether the classification of stone monument diseases based on phenomenon or cause (Li, 2014). And some terms describing the stone monument diseases have yet to be standardized. Nevertheless, the main disease types of stone monuments can still be identified on the basis of the existing research. Based on the "*Technical specification for evaluating disease of movable collection - Stone*" (State Administration of Cultural Heritage of the People's Republic of China, 2014) and the "*Classification and legend on the deterioration of ancient stone objects*" (State Administration of Cultural Heritage of the People's Republic of China, 2008) issued by the State Administration of Cultural Heritage of the People's Republic of China, this paper analyses the nature and manifestations of stone monument diseases. It examines the nature and manifestations of stone monument diseases in order to identify the needs of mapping science and technology in the extraction and analysis of stone monument diseases.

According to the "*Classification and legend on the deterioration of ancient stone objects*", there are seven major categories of stone monument diseases and 21 types of diseases manifestations.

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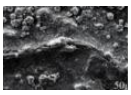
Disease Category	Disease Type	Disease Definition	Disease Character	Disease Picture
Biological Colonization of Stone Monuments	Plant Disease	Because of plants grow in the cracks of stone monuments, they destroy the stone by root cleavage.	Activity Disease Inducibility Disease	
	Animal Disease	Because of insects, rats and so on, they build nests, multiply, excrete secretions or erode stone monuments on the surface, hollow and cracked part of stone monuments.	Activity Disease Inducibility Disease	
	Microbial Disease	Microorganisms grow and multiply on the surface and cracks of stone monuments, leading to surface weathering of stone monuments.	Activity Disease Inducibility Disease	
Mechanical Disruption	Disintegration	Especially refers to a fracture and dislocation phenomenon with penetration and obvious displacement.	Stability Disease	
	Partial Loss	Partial loss and damage of stone monuments。	Stability Disease	
Surface Weathering	Surface Granular Disintegration	Periodic changes in temperature and humidity, freeze-thaw, water and salt activities cause the phenomenon of surface granular disintegration on the stone monuments.	Activity Disease Inducibility Disease	
	Surface Salt Crystal	Due to the activity of capillary water and soluble salt, soluble salt is enriched and precipitated on the surface of stone carving.	Activity Disease Inducibility Disease	
	Surface Flake Exfoliation	Due to the disturbance of external force, the destruction of water and salt, and the change of temperature cycle, the phenomenon of flake and plate exfoliation on the surface of stone monuments is caused.	Activity Disease Inducibility Disease	
	Warp and Exfoliation in Scales	Due to the large change in environmental temperature, the surface of stone monuments that are prone to thawing or fire have warped and exfoliated.	Activity Disease Inducibility Disease	
	Surface Solution	Stone monuments that have been washed by rain for a long time, and the pit or groove shaped dissolution phenomenon formed on the surface.	Activity Disease Inducibility Disease	
	Cavernous Weathering	The surface of stone monuments dissolves and soft inclusions dissolve with fall off, forming the weathering phenomenon of holes.	Activity Disease Inducibility Disease	
Cracks and Hollows	Mechanical Fissure	Cracking phenomenon of stone monuments caused by external force disturbance, uneven force, foundation settlement, stone structure, etc.	Activity Disease Inducibility Disease	
	Superficial Fissure	Cracks developed along the stone texture due to natural weathering and dissolution.	Activity Disease Inducibility Disease	

	Structural Fissure	Stone itself with structural fissure.	Activity Disease Inducibility Disease	
	Hollowing	The surface layer of the stone monuments bulges and separates into cavities, but they are not completely exfoliation.	Activity Disease Inducibility Disease	
Surface Contamination and Discoloration	Air and Dust Pollution	Stone carvings are stored in the open air. It's surface usually covered with a lot of dust and weathering products.	Stability Disease Activity Disease Inducibility Disease	
	Rust Crust	Stone monuments are stored or have been stored in the open, the crusts formed on the surface of stone carvings.	Activity Disease Inducibility Disease	
	Human Pollution	Contamination of stone monuments caused by graffiti, writing and soot.	Stability Disease Activity Disease Inducibility Disease	
Painted Stone Surface Pigment Disease	Surface Pigment Loss	The pigment cementation of the painted stone carving layer is aging, which leads to the loss of the color paint.	Activity Disease Inducibility Disease	
	Surface Pigment Crisp Powder	The pigment cementation of the painted stone carving layer is aging, which leads to the crisp powder of the color paint.	Activity Disease Inducibility Disease	
Cement Repair	Cement Repair	Use cement materials to bond, reinforce, repair and other changes to the original appearance of monuments.	Stability Disease Activity Disease Inducibility Disease	

Table 1 Classification and definition of stone monuments diseases

In addition, in "*Technical specification for evaluating disease of movable collection - Stone*", the corresponding measurement items required for various stone monument diseases are also specified in detail.

	Measuring Project				
Disease Name	Diseases Number	Disease Length	Disease Area	Disease Depth	Disease Volume
Disintegration	√				
Loss	√				√
crack	√	√	√	√	
Hollowing	√		√	√	
Hole	√		√		
Surface Solution	√		√		
Surface Granular	√		√		
Surface Salt Crystal	√		√		
Flake Exfoliation	√		√		
Warp	√		√		
Rust Crust	√		√		
Surface Contamination	√		√		
Plant Disease	√		√		
Animal Disease	√		√		
Microbial Disease	√		√		
Surface Pigment	√		√		

Loss					
Surface Pigment Crisp Powder	√		√		

Table 2 Stone monument disease survey project

3. ANALYSIS OF THE RESEARCH STATUS OF STONE MONUMENT DISEASES BY KEY TECHNOLOGY OF SURVEYING AND MAPPING

Surveying and mapping technology is a technology for acquiring spatial information based on information science, spatial science, and computer technology, with GIS, RS and GNSS technology as the core (Liu, 2020). It can be used of measuring, mapping, and modelling the size, shape, and spatial location relationships of natural geographical elements. Recently, surveying and mapping technologies represented by 3D laser scanning (Thamir, Abed, 2020), close-range photogrammetry (Hou, Bu, 2019), UAV oblique photogrammetry (Molnar, 2018), multi/hyperspectral (Cerra et al., 2018) and industrial cameras (Guo, 2017) have developed rapidly. By the characteristics of non-destructive and high-precision, it is gradually being applied to the detection, extraction, and analysis of stone monument diseases.

3.1 3D Laser Scanning

3D laser scanning technology as a high tech is another technological revolution after GPS in surveying and mapping field. This technology obtains the three-dimensional information of the object’s surface measured up to submillimeter accuracy by the method of high-speed laser scanning measurement. Wang Hao and his team have measured the stone structural plane, crack distribution, occurrence, spacing and other information of Thousand-Buddha cliff inscription and obtained the point cloud data of with the overall point accuracy<2mm,texture point accuracy<1mm though 3D laser scanning technology (Wang et al., 2016). He Yong has built three-dimensional information digital archive about Yungang Grottoes through 3D laser scanning technology and close-range photogrammetry with accuracy less than 3 mm error (He, 2016). Peng Yong and his team have completed relic model’s features that error less than 1mm through 3D leaser scanning technology (Peng et al., 2016). B. Davidde Petriaggi and his team have confirmed that 3D leaser scanning technology is available under the water, also have built models and obtains the surface of relief’s information up to submillimeter accuracy (Petriaggi, Ayala, 2015). Jiang Xiaoxi and his team have given an analysis method based on 3D Leaser scanning technology and numerical simulation technology about the rock pillar monuments with complex shape (Jiang et al., 2016). Shi Junli has calculated the Cave 11 of Yungang Grottoes’ three-dimensional model through 3D leaser scanning technology, also have analyzed the change about the spatial displacement and the stability about the structure (Shi, 2015). Wu Yuhua and his team have saved the three-dimensional information about the Thousand-Buddha cliff inscription and have recovered it in digital through the hyperfine 3D laser scanning technology, also they have applied this technology can be used in tracking the protection of the monuments (Wu et al., 2011).

3.2 Photogrammetry

Photogrammetry is the method of using optical photographs to achieve rapid acquisition and accurate collection of multi-angle textural features and high-precision three-dimensional information. Huang Shan and his team drew more than 252 grottos and Maiji mountain are drew 33 grottos based on Multi-Baseline Close-range Photogrammetry (Huang et al., 2016). C. Alyilmaz and his team have completed the feature extraction and morphological analysis of the surface patterns of Qubostan’s rock paintings (Alyilmaza et al., 2010). Yu Bingchen and his team have presented a way to rebuild unmovable monuments in high-precision, the accuracy can reach 0.5 mm (Yu et al., 2017). Chen Gang and his team have measured surface of the Stone Sculptures along the Spirit Roads of Tombs of the Southern Dynasties Period through UAV (Chen et al., 2017). Song has separated the details and built the model of the monuments through the industrial camera. The experimental results show the accuracy of it is 0.1 mm (Song et al., 2018). Hua Wei and his team have presented a method named“partition block”to extract information about the wall painting. It can correct the distortion of the wall painting, and restore the original color information of the wall painting (Hua et al., 2017). Xia Guofang and his team have obtained colors and structures’ information of the monuments’ surface through Photogrammetry technology and 3D leaser scanning technology. They also have completed the detection and measurement the surface of monument’s diseases through geometry, texture information collaborative feedback mechanism (Xia et al., 2018a). In the same year they have built high-fidelity colorful model through image transparent point mapping and 3D leaser scanning technology, which can be used for irregular monuments’ information collection and 3D monitoring works (Xia et al., 2018b).

3.3 Hyperspectral Remote Sensing

Hyperspectral Remote Sensing is a method of data collecting combines spatial and spectral features, which is due to have "integration of atlas" feature and concern. Ma Wenwu and his team have proposed a minimum noise fraction change method based on the threshold, and combine it with the hyperspectral technology to extract and analysis stone tablets’ characteristic information and raw material composition (Ma et al., 2015). Zhou Xiao and his team have used hyperspectral imaging to analysis Yungang Grottoes’ weathering condition, after normalized they can visualize the distribution of weathering diseases (Zhou et al., 2012). Sun Meijun and her group have collected different stages information of flaking of the murals disease to build a spectral library, also have used the PLSR assessment model realized the risk assessment of the flaking (Sun et al., 2016).

3.4 Thermal Infrared Imaging

Infrared imaging technology is a technical method for transform infrared radiation into a "thermal image". It has great effect for detection of the seepage in stone monuments diseases. Zhang Huihui have extracted image changes of rocks with different humidity under the lighting condition through infrared imaging technology, and proposed a thought to extract the thermal difference of the water-bearing property of rocks by differences (Zhang, 2013). Wu Yuhua and his mates have explored application of thermal infrared image technology in detecting cliff paintings encrustation，spalling and seepage diseases, also analysis the benefits of this technology (Wu, Liu, 2010a). In the same year, this team used the same technology to detect the seepage area, judgement of seepage quantity and division degree

of seepage are of Huashan rock paintings，which is located in Guangxi province (Wu, Liu, 2010b).

3.5 Analysis of The Advantages of Surveying and Mapping Technology

After analysis of the research above, surveying and mapping technology has been initially applied in the protection of cultural stone monuments. It also has obvious advantages in extracting the information in quantity, length, are and volume of cultural stone monuments. 3D laser scanning technology and close-range photogrammetry technology can provide substantial information of the disease’s characteristic of cultural stone monuments in a non-contact situation accurate acquisition and built fine three-dimensional model, and these technologies have remarkable effect on detecting the shape and color change of the disease of the cultural stone monuments. Hyperspectral remote sensing technology can obtain both image information and component information, it can provide reliable proof for qualitative and quantitative analysis diseases of cultural stone monument. Thermal infrared imaging technology is an important way to detect the internal disease information of cultural stone monuments, and it has great achievements in the structural analysis of cultural stone monuments and the detection of floods. Beside distinguishing features such as high surveying accuracy, high automatic extent, and strong adaptability, another significant advantage is non-contact, through this method without contact with the cultural stone monuments, the damage to the cultural stone monuments can be minimized, and the safety of the cultural stone monuments can be ensured. At the same time, surveying, and mapping technology as an effective way to obtain the noumenon of cultural stone monuments and the surrounding environmental information, can be used to provide basic support for the identification and quantify disease of the cultural stone monument. In addition, the achievements of surveying and mapping technology in various forms of expression, it can clearly reflect the spatial distribution and three-dimensional characteristics of cultural stone monuments diseases, it is convenient to analysis and comprehensive to exhibit.

4. THE PROSPECT OF SURVEYING AND MAPPING USING IN STONE MONUMENTS PROTECTION

In recent years, driven by emerging information technologies such as cloud computing (Cavalcante et al., 2016), digital twinsand (Uhlemann et al., 2017), artificial intelligence (Dong et al., 2021), surveying and mapping technology is gradually moving from numeralization to intellignetize. In order to meet the demand of stone monuments protection, surveying and mapping technology is necessary to conduct further research.

4.1 Define the applicability of surveying and mapping technology

Compared with other technologies, surveying and mapping technology in the field of cultural stone monuments protection in China is relatively late. In addition, there are many kinds of diseases of cultural stone monuments in China, and the representation is complex, and there is no clear classification standard, therefore, there are some problems in the way of how to detect the diseases. So, the feasibility of clear and definite surveying and mapping technology in the detection of cultural stone monuments disease, and clarify the relationship between various diseases and different mapping techniques, it is helpful to build up advantage of surveying and mapping technology in the cultural stone monuments protection.

4.2 Realization of intelligent data acquisition

Intelligent data acquisition is not only the development needs nowadays, but also the inevitable trend of surveying and mapping technology development. Compared with traditional surveying and mapping technology, measuring robot (Palaniappan et al., 2011), intelligent scanner (Scherer, 2005) and UAV and other intelligent mapping equipment have higher work efficiency and stronger environmental adaptability. Combined with cloud computing and other related technologies, it is expected to build an intelligent data acquisition system that can cover protection of the cultural stone monuments industry.

4.3 Build up a monitoring system of diseases

Diseases’ monitoring system is an important link in the protection of cultural stone monuments. We can realize the prediction of disease development trend after analysis the data changes of the diseases about the cultural stone monuments. So far, surveying and mapping technology is used in environmental monitoring, ontology monitoring and performance monitoring, if we analyze it with the cultural stone monuments disease, which can help to realize the evaluation of diseases, and to realize a foundation of preventive protection.

5. CONCLUSION

As mentioned above, the protection of cultural stone monuments in China started relatively late. There are still some problems such as classification of diseases accurately, classification of diseases and accurate extraction. To realize the scientific protection of cultural stone monuments and the rational analysis of diseases, we still need to discuss the choice of detection methods and the solution of monitoring system.

Today, surveying and mapping technology is closely integrated with the protection of cultural stone monuments, it is helpful to use surveying and mapping technology to realize information extraction and digital protection of cultural stone monuments. The author thinks that the technology of surveying and mapping has a good prospect, combined with the emerging information technology, it plays a significant role in the identification, extraction, evaluation, and monitoring of the disease of cultural stone monuments, also to realize a foundation of preventive protection about the cultural stone monument.

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