DESIGN OF INFORMATION COLLECTING SYSTEM TOWARDS THE SONG DYNASTY WOODEN HALL OF BAOGUO TEMPLE, NINGBO

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ABSTRACT:

Baoguo Temple is located half way up Lingshan Mountain in Northern Ningbo, Zhejiang Province, China. The main hall of Baoguo Temple is Song dynasty wooden structure. As the oldest wooden architecture in Jiangnan, China, it is a national major protective historical relic. In 2005, Baoguo Temple Ancient Architecture Museum was set up and opens to the outside world. From 2007, to be able to protect it more effectively and foreseeably, Baoguo Temple Ancient Architecture Museum began to build information collecting systems towards historical architectures using modern information technology. After comparing correlated studies both at home and abroad, we found that: heritage protection abroad started earlier than us, and it has already established thorough protection system, relevant protection mechanism, and also issued relevant protection laws and regulations. The technology which was utilized in protection abroad was not only limited in RS, GIS, GPS, VR, but also included many emerging technology such as using a computational fluid dynamics model to simulate the condition of temperature and humidity. The main body of this paper are going to talk about four parts: the first one is existing information system. In this part, we'll introduce the information collecting system, which was preliminarily built in 2007 in Baoguo Temple Ancient Architecture Museum. Using the modern digital computer information technology, researchers can gradually check and acquire the information of the material of relics, the condition of the structure stress and the natural environmental information, which may probably affect the cultural architecture. And this part may be divided into information collection, information management and exhibition. The second part is update scheme design of original information collecting equipment and technology. Original information collecting system of microenvironment is relatively independent and data haven't been included in the management of the system. The original sensors transmit signal by wire and it would be interfered each other when they work together, and then it may cause congestion sometimes. Otherwise, the original system has been working continuously for seven years and it can't adapt to the new computer hardware and operating system. Then, this part may be divided into data integration of information collection, equipment upgrading and adding of information collecting point, upgrade of information management and exhibition system. The third part is scheme design of newly added information collecting projects. After understanding the exposed disadvantages before, the added projects may include real-time information collection of groundwater level and quantity, surface water quantity and velocity, mountain landslide, vibration of the main hall, material of wood construction of the main hall, structure of the main hall, the condition of key components of the main hall, air pollution such as the concentration of SO_2, PM2.5, O_2, CO_2 and information collection of insect pest such as termite. After collecting information by many ways, the fourth part is to talk about comprehensive application of collecting information. This part may include comprehensive analysis of collecting information, management application of collecting information, publishing of collecting information and exhibition of information collecting system. Therefore, through this research, we want to develop information collecting work more perfectly and entirely and protect historical heritages more scientifically and effectively.

1. PROJECT BACKGROUND

Baoguo Temple is located half way up Lingshan Mountain in Northern Ningbo, Zhejiang Province, China. In March 1961, it was one of the first nominated for national Cultural Heritage Conservation Sites by the state Council. In 2005, Baoguo Temple Ancient Architecture Museum (http://www.baoguosi.com.cn/english/index.html) was set up and opens to the outside world. The temple retains many period ancient buildings from Tang Dynasty to the Republic of China. It is the real museum of ancient architectures.

The main hall, rebuilt in Northern Song Dynasty (1013 A.D.), is one of the oldest wooden architectures with best reserved buildings in South Yangtze River of China. It goes through all the vicissitudes of life and has been repaired many times, but still maintains the original shape.

The main hall has great historic, artistic and technical values. However, after going through millennium vicissitudes, there are some inevitable damages reducing the construction quality and influencing the building life.

From 2007, to be able to protect the historical relics more effectively and foreseeably, Baoguo Temple Ancient Architecture Museum began to build information collecting systems towards historical architectures. Using modern information technology, researchers can collect, manage, analyze and display the information of the main hall and its environment.

After more than seven years of collection, we have accumulated amounts of data, meanwhile we have found the deficiency. This design is an update and supplement.

2. CORRELATED STUDIES BOTH AT HOME AND ABROAD

2.1 Correlated Studies at Home

The information collection of cultural heritage is powerful guarantee and means of foreseeable protection. [1]

Recently, in our country, experts use RS and GPS to acquire the spatial information and satellite images of the places of cultural heritage during the protection. [4]

In the heritage survey of Xinjiang area, researchers use RS and satellite images to find the sites, use GPS to locate and track, and then do the spot investigation. [5]

The Grand Canal of China is used lots of spatial information technology, such as RS, GIS, GPS, VR and etc. It can realize intelligent identification, positioning, tracking, monitoring and management by the Internet of things. It also can realize risk assessment and warning, which based on the platform of GIS management system. [3]

The West Lake is used ArcGIS as floor layer technology, integrating with many technique modules, such as video, sensor, GPS and intelligent video. It can gather all the real-time monitoring system in the scenic spot by using many kinds of sensing devices and image monitoring equipment. [6]

We can collect the information of factors of natural disaster risks by using RS and GIS. We also can use RTK to collect the information of deformation of the architectural heritage. [7]

INNOVA 1412 Photoacoustic Field Gas-Monitor can make comparison analysis of the exchange rate of the air indoor. The microenvironment information collecting station can uninterruptedly collect the information of factors of the temperature, humidity, CO_2 and the number of tourists. [8]We also can use infrared thermal imaging technology to collect information of humidity.

Aiming at collecting information of interior deformation of the architecture, we can use digital radioactive perspective technology, ultrasonic detection method and stress wave detection method.

Brillouin Optical Time Domain Analyzer (BOTDA) is very suitable for collecting information of structure. It can collect information of whole process of crack development. It also can suitably collect the whole life healthy information of structural mechanics level and material level in a long term. [9]

Starting from analyzing the material, collecting information can use many technical instruments like X-ray diffraction analyzer, X-ray fluorescence analyzer, infrared spectrometer and environmental scanning electron microscope. The Internet of things plays a role in real-time information collection and information collection when experts study on the performance variation of building material, performance variation of single component mechanical and deformation of the whole structure. [7]

2.2 Correlated Studies at abroad

Heritage protection abroad started earlier than us, it has already established thorough protection system, relevant protection mechanism, and also issued relevant protection laws and regulations. In the work of collecting information, it has already established scientific index system. About the technology of collecting information, developed countries start to use spatial emerging technology to collect the information of cultural heritage. In addition, they use data and information to do the analysis and assessment, and then, it can support the protection and management of cultural heritage.

Researchers like Emilio Marengo (2011) utilized multi-spectral imaging, multivariate analysis and statistical process control theory, it can automatically detect the damage or potential degradation changes of the cultural heritage. [10]

Ground-Based Synthetic Aperture Radar Interferometry (GBInSAR) and Terrestrial Laser Scanning (TLS) were purposely integrated to obtain 3D interferometric radar point clouds to facilitate the spatial interpretation of displacements affecting archaeological monuments.[11]

In the research of protection of cultural heritage in Italy, experts like Fabio Leccese (2014) put forward a new acquisition and imaging system for environmental measurements based on layered architecture. [12]

Researchers (2014) created an upgrade device based on quartz crystal microbalances. This novel device is provided with on-board sensors for simultaneous measurement of temperature, relative humidity and light intensity and its type. [13]

Experts (2014) utilized nuclear magnetic

resonance sensors which can be applied in situ for non-destructive and non-invasive investigations. According to the proton density, transverse relaxation time and self-diffusion coefficient, they can collect the information of interior material structure, such as the water content, stratification and the thickness. [14]

Scholars like Delia D'Agostina (2014) used a computational fluid dynamics (CFD) model, to simulate the condition of temperature, relative humidity and air velocity, which were responsible for, salts crystallization and artworks deterioration. [15]

When scholars (2014) studied the effect of solar radiation and humidity on the inner core of walls in historic buildings, according to acquire the inner condition, they use a new facility, which called MEMSIC instruments to collect information. [16]

3. EXISTING INFORMATION SYSTEM

In 2007, an information collecting system towards the main hall itself and its environment was preliminarily built in Baoguo Temple Ancient Architecture Museum. Using the modern digital computer information technology, researchers can gradually check and acquire the information of the material of relics, the condition of the structure stress and the natural environmental information, which may probably affect the cultural architecture.

3.1 Information collection

In 2003 and 2009, Research Institute of Wood Industry, Chinese Academy of Forestry explored the materials of wooden structure towards the main part of the main hall twice.

According to this exploration, researchers can assess the timber component, especially the condition of decaying, insect bite, cracking, fracture and the degree of damage. At the same time, it can identify tree species of the main bearing timber component, judge historical marks of maintenance and make sure the structure of timber component like melon-shaped column.

After exploring, researchers found that moisture content of some parts of timber components was relatively higher up to 26%. There are eight tree species composing the structure of the main hall, including Cunninghamia lanceolata, Pinus, Diptercaropus tubinatus Gaertn.f., Picea, Castanopsis kawakamii Hay., Yellow cypress, Castanea mollissima and Glyptostrobus pensilis.

At present, there are obvious phenomena of retroversion of the Great Buddha's Hall. Ningbo Metallurgical Investigation & Design Research CO.,LTD collects the information of deformation and settlement of the main structure every year.

They finished the first measurement on Nov.18, 2007. After another six measurements, the eighth measurement was end on Apr.21, 2014.

From the data, we can see that the southeast part of the main hall sedimentates obviously, and the whole part is going to incline to the northeast.

In 2012, researchers made a detailed exploration of the foundation. They used drilling, sampling, in situ test, measurement and positioning, integrating soil test indoor, to collect all kinds of information exactly and comprehensively.

At the same year, researchers from Structural Engineering Institute of Zhejiang University arranged sensors to collect the structural information of Baoguo Temple. It can detect health state of the structure after the rainy season. According to the data of beam, column and node, which is recorded, by BOTDA, FBG and Vibrating Wire Transducer, experts can assess the characteristic of the structure and the health state towards the Baoguo Temple.

In 2008, Ningbo Dongsheng Harmful Biological Control Limited Company installed 19 information collecting stations outside of the green belt, under the slabstone and around the wing-room of the main hall. After one year acquiring, researchers checked it every season once or twice.

The result of information collection was that there were no living termites underground around the main hall, but they found termites at one station which is close to the east wing-room.

In 2007, researchers from Tongji University arranged sensors to collect information automatically from 9 azimuths of the plane of the main hall. This information included the temperature and humidity indoor, wind speed, wind direction and rainfall outdoor.

In 2009, they arranged professional five-element automatic weather station to measure the temperature, humidity, wind speed, wind direction and rainfall outside the door.

Baoguo Temple is located half way up Lingshan Mountain with a steep slope behind it. The stabilization of back mountain body will influence the safety of all buildings in the temple directly. At present, the exploration of back mountain body is under way, the relevant conclusion will be given recently.

3.2 Information Management and Exhibition

It is essential to establish information management and exhibition system to manage abundant information of cultural relic buildings uniformly.

This system can be divided into data storage module, data processing module, data mining module and data exhibiting module.

After analyzing the collected information for a period, we can understand the change law of cultural relic buildings; make sure the safe, warning and active critical point of detection value. It can provide rich practice and theoretical basis for protection and maintenance of relics, and it also can provide scientific countermeasures and data supporting sustainably to clear hidden danger on time as much as possible. Meanwhile, we can understand the relationship between the change of surrounding natural environment and the change of cultural relic itself. After that, we would find the main environmental factors, which influenced relics, and protect it targetedly. Make sure to address both the symptoms and root causes, nip it in the bud.

Based on some preliminary 3D model, the data of collection and the information of data processing, data mining can be showed to the audience directly and interactively. Besides that, it would add some games to let audience understand much more meanings of the information deeply.

4. UPDATE SCHEME DESIGN OF ORIGINAL INFORMATION COLLECTING EQUIPMENT AND TECHNOLOGY

4.1 Data Integration of Information Collection

Original information collecting system of microenvironment is relatively independent. The data haven't been included in the management of the system, so it won't take part in comprehensive analysis which cultural relics management would need in the future. Therefore, we need to program a professional specific computer program. Through this program, the acquired data can be transformed and combined into a new system of protection information collection and management, which can be a subsystem.

The original structural information collecting system collects the displacement and settlement of the main structural members and parts by traditional mapping once a year. This part is also relatively independent. The data is saved by text format and it's hard to join the comprehensive management data analysis. Therefore, these data also need to be transformed and combined into the new system.

4.2 Equipment Upgrading and Adding of Information Collecting Point

Original sensors transmit signal by wire, it would be interfered each other when many sensors work together, and it may cause congestion sometimes. This upgrade will utilize wireless sensors to transmit signal by Zigbee.

There are only 9 existing point, which located in eight orientation and middle of the plane of the main hall, to collect information of temperature and humidity. However, because of the larger space height, there are big differences of the temperature and humidity between the place near ground and roof. Therefore, in order to investigate the change of temperature and humidity everywhere of the main hall totally, it needs another 18 sensors to collect information in all direction by setting three high levels.

4.3 Upgrade of Information Management and Exhibition System

Original system has been working continuously for seven years, and it can't adapt to the new computer hardware and operating system. Otherwise, the original relatively independent information needs to be integrated into the new system by programming a specific program.

It merely collects all kinds of information and data by original system, but in the new one, we would add management functions of cultural relics. The data need real-time analysis, and it may play the role of warning on time. We would add real-time data processing analysis, such as warning before moisture condensation of the environment, and then effective intervention can be actively taken to improve the level of cultural relic management.

Original exhibition of collecting information was limited in Baoguo Temple only. We can integrate new information collecting and management system with international internet fully, with using current advanced technique which called "cloud", to let the collecting data be used in a more extensive range.

5. SCHEME DESIGN OF NEWLY ADDED INFORMATION COLLECTING PROJECTS

5.1 Real-time Information Collection of Groundwater Level and Quantity

After more than seven years collection, the main hall is indeed having uneven settlement, and the main factor lies in foundation. The decline of water level of groundwater would cause settlement, and it may influence the cultural architecture on the ground. Therefore, we need to collect information of the change of groundwater's level around the architecture for a long time continuously. We can study on the relationship between the change of groundwater level and the settlement of foundation by analyzing the data which combined collecting information of groundwater level with real-time information of settlement.

The content of information collection includes: location, water level and rate of increment (or decrement).

5.2 Real-time Information Collection of Surface Water Quantity and Velocity

Weather in Jiangnan is rainy, and the rainwater would scour the foundation of cultural architecture when it flows through Baoguo Temple. Therefore, it's necessary to collect information of surface water. There are drain in the temple and stream outside; we can collect real-time information of water quantity and velocity.

The content of information collection includes: location, water level, water quantity and water velocity.

5.3 Real-time Information Collection of Mountain Landslide

Baoguo Temple is located half way up Lingshan Mountain; A small reservoir is located on Fengshuping at northeast corner of the temple; Ningbo belongs to Jiangnan rainy area. Therefore, the stability of mountain may influence the safety of Baoguo Temple directly. After collecting information of the mountain by GPS satellite positioning and microseismic technology, it can make long-term, mid-term and short-term predication of geological hazard.

The content of information collection includes: location, slides direction, slide distance and slide velocity.

5.4 Real-time Information Collection of Vibration of the Main Hall

At present, it still exists constructing with larger vibration around Baoguo Temple. With the construction and development of Ningbo industrial area at southeast and the construction of its surrounding traffic facilities, especially the

construction and opening of expressway under the mountain in recent years, the factors of vibration will increase gradually. Therefore, it's necessary to collect information of the condition of vibration for a long time continuously.

The content of information collection includes: location, vibration time (start and end), vibration amplitude and vibration frequency.

5.5 Real-time Information Collection of Material of Wood Construction, the Main Hall (such as Moisture Content)

Main material of Baoguo Temple is wood. The texture of wood is relatively loose, and it would contain moisture all the time by itself. The change of its surrounding environment may cause swell-shrinking deformation of wood, and then the internal stress and distance, which is created by a long time again and again, is also harmful to the buildings. Otherwise, wood with high moisture content would mildew and rot easily, and damage the cultural architectures directly. Therefore, it's necessary to collect information of main wooden construction's moisture content of the main hall for a long time continuously.

The content of information collection includes: location, moisture content of wood.

5.6 Real-time Information Collection of Structure of the Main Hall

It can't acquire the instantaneous and dynamic information of structure of the main hall by collecting information of structural displacement and sedimentation once a year. Especially influenced by summer typhoon and winter snow, we plan to develop a real-time dynamic displacement information collecting system, based on laser displacement sensor, to collect real-time and dynamic information of deformation of the structure, which was affected by temporary external force.

The content of information collection includes: location, deformation time (start and end) and deformation degree.

5.7 Real-time Information Collection of the Condition of Key Components of the Main Hall

Some timber components of the main hall are thousand year old, and their real-time condition information needs to be collected emphatically. These key components include important structural stress position, existing heavily damaged position, components like mortise and tenon with obvious displacement, hidden components like inner of ceiling and etc.

The content of information collection includes: location and real-time video.

5.8 Information Collection of Insect Pest Such as Termite, Carpenter Bee, Barefoot Bee and Moth

Wood structure buildings suffer from invasion of harmful organism anytime, especially the insects, which eat wood or nest in the wood. Although some components of Baoguo Temple are yellow cypress which can bear insects biting, there are much more

wood structure being damaged by termite, carpenter bee, barefoot bee and moth. Therefore, it's essential to collect information of these insect pests.

The content of information collection includes: location, type of insect pests and their quantity.

5.9 Real-time Information collection of Air Pollution Such as Concentration of SO_2, PM2.5, O_2 and CO_2

In recent years, as the rapid development of Ningbo city, urban scope is extending to the north mountain area, near Baoguo Temple. The air pollution, which is produced by industrial production and city life, is aggravating gradually. Motor vehicle on the expressway in front of Baoguo Temple is a source of harmful gas, which can't be ignored.

In this harmful gas, SO_2 is the most common acid gas and it would bring huge damage to the cultural relics. Otherwise, CO_2 and PM2.5 also bring huge damage to the exposed cultural architectures. It's necessary to collect real-time information of these air pollutions.

The content of information collection includes: location, type of gas and its concentration.

6. COMPREHENSIVE APPLICATION OF COLLECTING INFORMATION

6.1 Comprehensive Analysis of Collecting Information

Since 2007, we have accumulated all kinds of information of the main hall of Baoguo Temple by information collecting system. However, these data have not been enough analyzed. Especially the relationship with the state of relics, it needs further cross-disciplinary study from various aspects.

As improving the projects of information collection, the data analysis would be taken seriously. We will step up efforts on analyzing by inviting various aspects of experts at regular intervals.

Information collection can't only be limited in the museum for field study, but also can attract more people to take part in by opening information properly on the Internet.

As there are more and more contents of information collection, the collection time would cost longer and longer, and the whole information collecting system will produce amounts of data.

6.2 Management Application of Collecting Information

The final purpose of collecting information of Baoguo Temple and its environment is to protect cultural relics more scientifically and effectively. We can find the relationship between consequence of information collection and state of cultural relics by comprehensive analysis above, and we can also acquire the key early warning value among the management and protection of relics. With programming a professional software program, we try our best to make real-time analysis calculation come true. After comparing with the presupposed early warning value, this system would output prompting message to guide managers, even control the

equipment directly, to preserve cultural relics when it's near or reached the early warning value.

6.3 Publishing of Collecting Information

At present, the collecting information of the main hall is stored in Baoguo Temple limitedly, only little professionals can acquire and study on these data. For extending the scope of using them, it's necessary to be published by some platform. The information collected every year was arranged into volume by textual form, and it doesn't suit to publish amounts of data. Once collecting information transform to textual form, it's hard to make statistical analysis automatically. Therefore, it needs a computer system to publish collecting data.

Using cloud computing, it can not only publish collecting information, but also can finish real-time analysis and research on the internet by it. Certainly, the collecting information itself can be stored or backup on cloud directly.

6.4 Exhibition of Information Collecting System

Now, Baoguo Temple is a museum displaying architectural relics from Tang Dynasty to the Republic of China. It undertakes an important business to play a role of bearing, spreading, promoting and inheriting our cultural. Besides exhibition of itself, it's very necessary to display the process and relevant scientific technology of the protection. It's benefit for people to raise their consciousness to concentrate on the protection of cultural architectures. Therefore, the information collecting system of the main hall and its environment is necessary to be displayed in a way.

7. CONCLUSION

In 2007, Baoguo Temple started to collect information of cultural protection by a preliminarily system. After seven years, the original system exposures some disadvantage, at the same time, it still creates data stably and continuously. Information collecting technology and practical work of conservation at home and abroad are among the rapid progress and conduction. Therefore, through this research, we want to develop information collecting work more perfectly and entirely, try our best to enhance basic research, try to link information collecting work closely with cultural relic management, master the state of cultural relics and protect them on time more scientifically and effectively.

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