THE RESEARCH AND APPLICATION OF SPATIAL INFORMATION TECHNOLOGY IN CULTURAL HERITAGE CONSERVATION — CASE STUDY ON GRAND CANAL OF CHINA

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ABSTRACT:

This work is part of a multidisciplinary research project, within the National Key Technology R&D Program, "The Research and Application of Spatial Information Technology for conservation of large-scale heritage sites", developed in collaboration with archaeologists and researchers from the field of geoinfomatics and hydrology, which aims at the application of spatial information technology for cultural heritage conservation, especially the large-scale heritage sits, a case study on Grand Canal of China is carried out. This paper presents the principal achievements we have gotten and puts forward some challenging issuers accordingly. At first, the related definitions are discussed; and some successful cases are reviewed. After the review, an integrated framework for the application of spatial information technology in conserving cultural heritage is conceived, based upon analysis of whole conserving process, information transferring flow, and domain model. Then the content and framework of this research project are studied by the logic and technical structure. Some key methods involved are discussed subsequently; also the main results and new findings are investigated in details. Finally combing with the opinions from experts of cultural heritage conservation, this paper concludes the project's established results objectively, and present the research plan in the future. The involved contents of this study could be found on http://geospatial.arch.tsinghua.edu.cn, a website developed for this project especially.

1. INTRODUCTION

There are many successful examples indicating that spatial information technology (SIT) is very useful and necessary to conserve historical cultural heritages, including the serial processes of prospecting, investigating, extracting, preservation planning, documenting and monitoring. Especially Geography Information System (GIS) and Remote Sensing (RS) have been widely used to carry out related activities.

1.1 Cultural Heritage and Cultural Heritage Conservation

A concise discussion and perhaps definition of "cultural heritage" and "cultural heritage conservation" is conducted here in order to confine the scope of this study, and ensure the common understanding of the terms mentioned in this paper.

1.1.1 Cultural Heritage

Cultural can be represented by material objects like buildings, paintings and monuments, but also non-material manifestations like language, dance, song, cuisine, custom, religion, landscape, literature, art, philosophy and, even television programs (Ogleby, 1995). In 1954 the General Conference of UNESCO adopted the term, cultural heritage, as an international convention on the Protection of Cultural Property in the Event of Armed Conflict (known as Hague Convention), which refers cultural property as tangible and physical objects. The similar meaning can be found from the famous Convention Concerning the Protection of the World Cultural and Natural Heritage in 1972, also by General Conference of UNESCO. For the sake of this study the above meaning will suffice as it is generally accepted. Much of this paper will concentrate on SIT applications to material cultural heritage, but it will also address some issues of intangible cultural heritages along Grand Canal of China (GCC).

1.1.2 Cultural Heritage Conservation

Following the hints of above dissertations, it can be discerned an integral process of cultural heritage conservation should at least include 1) prospecting for cultural heritage and investigating correspondingly; 2) evaluation of cultural heritage, including its values, preservation status, potential hazards and so on; 3) establishing and carrying out reasonable preservation planning; 4) effective monitoring on cultural heritage and feedback in time. In the section 2, a flow chart of applying SIT in each aspects of cultural heritage conservation will be brought out and discussed detailedly.

1.2 SIT Applied to Cultural Heritages Conservation

1.2.1 Digital Recording and Analysis Based upon GIS

Last decades witnessed the rapid increase of applying GIS to preserve cultural heritage. GIS is mainly used for cultural resource inventory applications, protections planning, impact assessment studies, facilities management and archaeological research applications. In 1990s UNESCO utilized GIS to integrate data efficiently from the field of archaeology, geography, hydrology, weather, environment and demographic data in the Angkor Zoning and Environment Management Plan, Cambodia. Then the usefulness of GIS was demonstrated in other UNESCO pilot sites at Hue, Viet Nam and Vat Phou, Lao PDR and other sites in Europe, Australia and North America (Paul Box, 1990).

GIS, especially spatial analysis plays a significant role in archaeological research, etc, landscape archaeology, predictive

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location modelling. Based upon a filed archaeology geography information syetem, archaeologist can predict the potential archaeological sites location, discover the pattern of prehistorical settlements, and realize relationship between settlements and topography through viewed analysis. In line with former studies on predictive modelling, Espa presented a GIS based method to produce probability maps of archaeological site locations automatically (Espa *et al.*, 2006). Using serration analysis, corresponding analysis and other spatial analysis methods, archaeologists study the occurrence of 157 bead types at 98 European Aurigacian sites to get the knowledge of the first anatomically modern populations colonising the European territory of their degrees of biological, linguistic, and cultural diversity at different settlements (Vanhaeren *et al.*, 2006). While other archaeologists conducted a case study at Bronze Age cairns of North Mull, Scotland applied rigorous statistical analysis and viewed analysis to studying the visible area (Fisher *et al.*, 1997).

1.2.2 Remote Sensing for Archaeology

Surface features caused by historic sites can be recorded by remotely sensed aerial and satellite imagery, including multispectral, hyper-spectral, and synthetic aperture radar imagery. With the capacity of detecting, cataloguing, differentiating and classifying surface and near surface underground historical relic features, remote sensing can get better realization of the features, their patterns, textures, size, association, and so on, and plays an important role in the investigation, prospection, and management of various cultural heritages.

Information extracted from radar imagery, multispectral imagery, hyperspectral imagery, thermal infrared imagery, panchromatic and colour infrared imagery, combined with field surveying, had been used to look back in time and trace clues of ancient civilization, showing the value of modern technology to help us find the history recorded on Earth's surface (Fisher *et al.*, 1999; Trelogan *et al.*, 1999; Blom *et al.,* 2000; Tan *et al.*, 2006). In particular, Air photos, ETM+, and TM images were utilized as major tools in archaeological investigation to indentify the boundaries of the historical sites of Persepolis (Behnaz Aminazadeh *et al.,* 2006). In addition, Kucukkaya reported a series of topics at session Q2 of the Fifth World Archaeological Congress (WAC5) which aiming to address the problem of the management of cultural heritage and archaeological areas with remote sensing (Kucukkya, 2004).

1.2.3 Visual Methods for Cultural Heritages Conservation

Recently the methods necessary for utilizing three-dimensional(3D) visualization and virtual reality in modelling, simulating, digital preserving, auxiliary restoring of historical cultural resources and environment have been studied carefully. During the restoration process of an ancient bronze statue, the Minerva of Arezzo, located at Museo Archeologico in Florence, complete 3D digital models of the Minerva were produced to keep track of the variations that occurred during the restoration process, up to the final acquisition of the form of the restored artwork (Fontana et al., 2002). Especially virtual reality (VR) was applied to develop 3D visualization tools and support virtual archaeology activities (Allen et al., 2003; Vote et al., 2002). Furthermore Winterbotom used geographic information systems (GIS) based analyses and VR reconstructions, to explore landscape context for two types of Neolithic monuments: cup and ring rock art and a stone circle, then suggested that VR would be useful to explore visually rich representations of past environments for site interpretation, present uncertainty and test different scenarios for landscape archaeology context (Winterbottom et al., 2006).

1.2.4 Other Useful Methods: The development of alternative techniques and methods for the cultural heritage conservation has been identified as an important aspect in the last years. A remarkable case is that Global Position System (GPS) is wildly applied to archaeological prospection, spatial data acquisition, 3D geometric modelling and other potential use. Additionally 3D laser scanning addresses problem of modelling, detecting the minor transformation of statue and valuable construction quickly.

Based on high-resolution micro-topographical data generated by GPS surveys, Chapman brought forward a new archaeological prospection technique for wetlands, and conducted a subsequent programme of ground truthing to demonstrate the value (Chapman *et al.*, 2001). In 2007, Losier presented a procedure developed to generate 3D models from GPS positions taken at the top and the bottom of the excavation units boundaries on the archaeological site of Tell Acharneh, Syria; the results showed that comparing with the usual procedure, with a theodolite or a total station, the work in the field with a GPS RTK allowed archaeologists to collect more points of an excavation unit within the same time period, and build a 3D geometrical modelling of extraction units easily (Losier *et al.*, 2007).

2. METHODS AND PROCEDURE

2.1 The Study Area

The Grand Canal of China, a masterpiece by ancient Chinese similar to the Great Wall, stretching from Hangzhou in the south to Beijing in the North, is the world's longest and oldest man-made waterway (Figure 1; Figure 2). It is about 1,794 kilometres long, and connects five major water systems, including the Yangtze and the Yellow River. As a whole, The Canal was built, section by section, in different areas and under different dynasties, started form 5th century B.C. and complete by the year 1327. The Grand Canal of China, as the main transportation linking the nation's capital city in the fertile northern region to its most affluent territory in the southern region, promoting economic and cultural exchanges and strengthening the unification of the country, played a significant role in the history of China. Needham estimated(Needham, Joseph, 1971), "Nothing remotely approaching the Chinese canal systems existed in Europe until the four great seventeenth-century canals in France,……even by 1893 the total mileage of French canals had only reached three times the length of China's Grand Canal alone in 1300."

With a profound history more than 2400 years, a unique culture and folk customers associated with the canal's evolution, formed. Along the canal, there are countless magnificent cultural relics, and the canal has been hailed as "a long corridor of ancient culture", and "a show room of folk customs". In the year of 2006, State Administration of Cultural Heritage added the Grand Canal of China on the list of heritages to apply for World Cultural Heritage to UNESCO. Several research projects are carried out to strengthen the preservation of the canal. This study is one of the research projects, and plans to employ spatial information technology to backup the preservation because of the canal's unique spatial-temporal characters, help general peoples, professionals and governments enhancing their realization, research and management of the canal, especially to support the proposing for world cultural heritage with detailed cultural heritage document and excellent spatial information management.

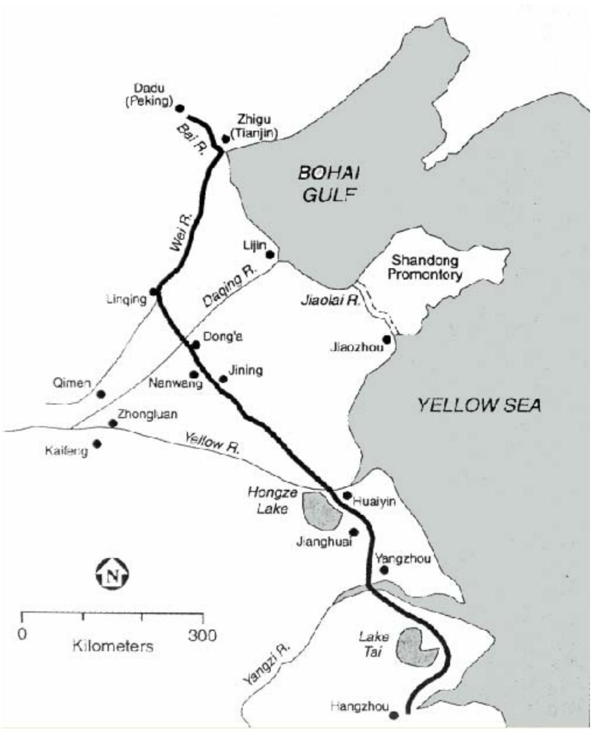

Figure 1. Grand Canal during the Yuan Dynasty, 1280-1367 BC Adapted from Leonard (1996)

2.2 The Framework of SIT Applied to Conservation GCC

Based upon the analysis of current practice of cultural heritage conservation in China, a comprehensive framework showing the application of SIT is proposed (Figure 3). At first, the whole process is divided into several parts, investigating and prospecting cultural heritage, assessing heritage's value, determining conservation grade, establishing and implementing preservation plan, monitoring and feedback timely. During each single part, there are many methods of applying SIT to carry out the corresponding protecting activities as discussed in part 1 of this paper.

For protecting and investigation, GIS, RS and GPS technologies are integrated to indentify the cultural resources from their environments, and would keep a digital document completely. For assessing of heritages, there are value evaluation, health evaluation, and assessing of management condition, which would take use of the supporting ability of spatial information technology. After the step of evaluation, SIT can be used to fix grades of cultural resources into world heritage, national heritage, provincial heritage and county-heritage, taking account of laws, historical background, and local customs. Then the conservation plan would be issued and carried out to safeguard cultural property from grave-robbers, protect cultural sites from environment degradation, mostly related to unchecked urban development. SIT would be found necessary in this process as showed in the field of urban planning, where planning supporting system based upon GIS and VR has achieved great success (Geertman *et al.*, 2003). Finally RS is applied for regular checking and monitoring of cultural heritage, especially large-scale cultural site in order to acquire effective feed back.

On the basis of above application flow chart, the content of this research project is mainly organized into four proportions. The first one is to study and set up necessary standards for the application of spatial information technology in the field of cultural heritage conservation. The second part is the research of key technologies involved, including cultural relics investigating with remote sensing, reconstruction and 3D modelling of the canal and spatial analysis utilized in field archaeology. The third one is research and development of spatial data base, geography information system, conservation planning support system of the canal, and spatial data collecting system based upon GPS and PDA. Finally based upon the rich content of spatial database and established functions of above information systems, some thematic studies are carried out, in cooperation with professionals from hydraulic history and cultural heritage conservation, including evolutionary process of GCC, LUCC studies on certain sites, and the distribution of cultural heritages along GCC.

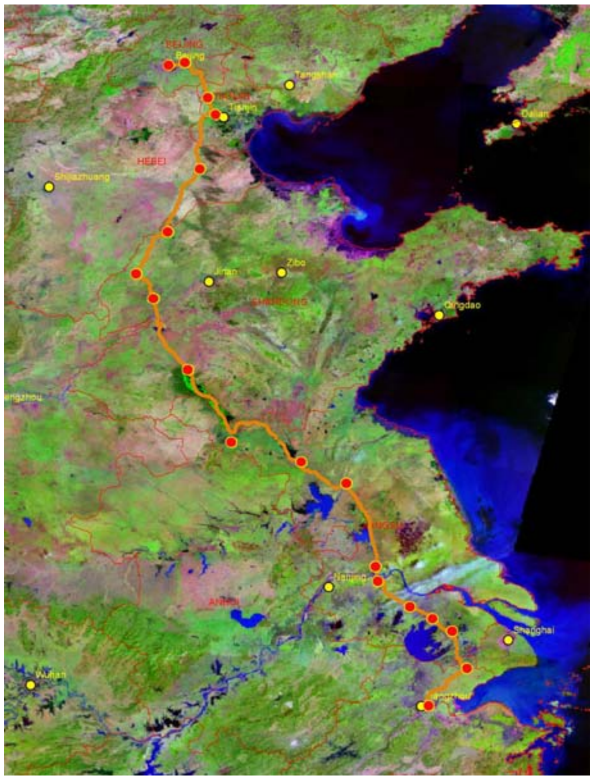

Figure 2. The Grand Canal of China on remote sensing imagery

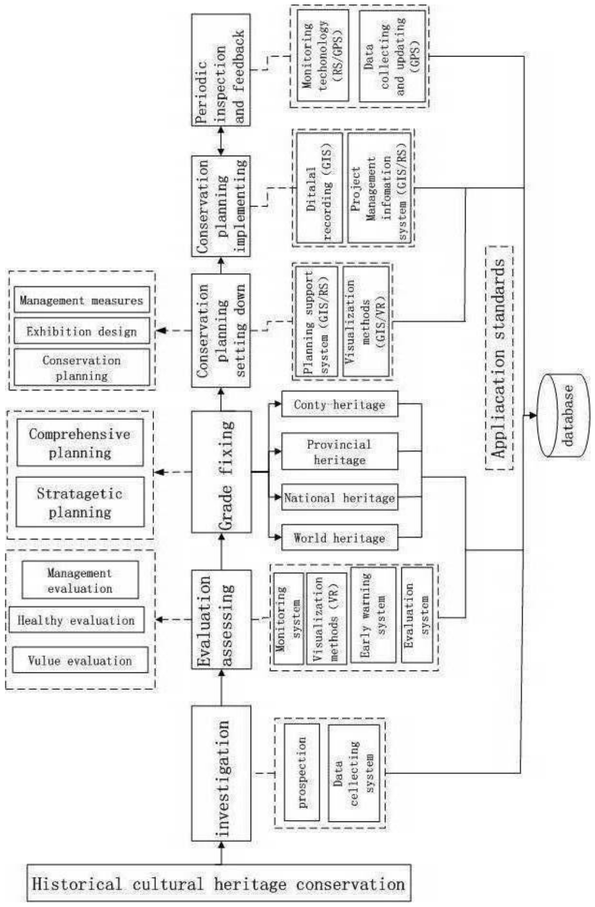

Figure 3. the flow chart for application of SIT in cultural heritage conservation

3. MAIN RESULTS FROM ESTABLISED STUDIES

3.1 Standards for applying SIT to cultural heritage conservation

Types of cultural resource along GCC are so diversiform that almost all known types of cultural heritages in other places of China could be found there, they may be hydraulic facility, historical architecture, statue, mausoleum, and so on. It appears necessary to set some standards to guide the attempt of get the information from remote sensing imagery, surveying results of GPS, and make sure the field investigations data, which holds the form of tables, graphics and archaeological reports, could be imported to the data base correctly. A series of standards are designed by experts of information technology, together with researchers of cultural resource conservation and professionals from field archaeology, including regulations of dada collecting with a custom PDA, standards for classifying and coding of cultural resources, rules for data types and data structures in spatial data base.

3.2 Information Systems for GCC conservation

On the basis of studies on key technologies, four information systems have been developed to support the conservation of GCC, including GIS system of GCC, 3D landscape simulation system, conservation planning supporting system, and data collecting system for field investigation based on customized PDA with GPS module. The first two systems are discussed particularly as follows.

3.2.1 GIS for GCC: A GIS system with two versions is developed for GCC conservation, which could be managed on desktop or visited via Internet (http://geospatial.arch.tsinghua.edu.cn) respectively, including spatial database, fundamental module as functions of general GIS system, and extended module for professional user(Figure 5).

Implementing with the tools of ArcSDE and Oracle 10g, the spatial data is organized into three levels with different scales (macro, meso and micro). At the macro-level, ETM (14 scenes) is used, together with the DLG at the scale of 1:250,000(14 pages). At the meso-level, there are SPOT 5 (42 scenes) and DLG with the scale of 1:50,000 (105 pages). All the spatial data at the above two levels respectively covers the extension of the canal. At the micro-level, QuickBird imagery is used for seven important historical sites or cities along the canal, Beijing (214 km^2), Tianjin (836 km^2), Cangzhou (410 km^2), Jining (215 km^2), Liaocheng (315km^2), Pizhou (925km^2), Hangzhou (321 km^2), together with DLGs at the scale of 1:10,000(392 pages) which also cover the canal with a given buffer. Except for data at the three levels, there are many precious old panchromatic air photo taken by American air force during the period of World War 2. Facing the huge amount of images and datasets, some methods are employed to improve the efficiency of the spatial data base (Shekhar *et al.*, 2003.).

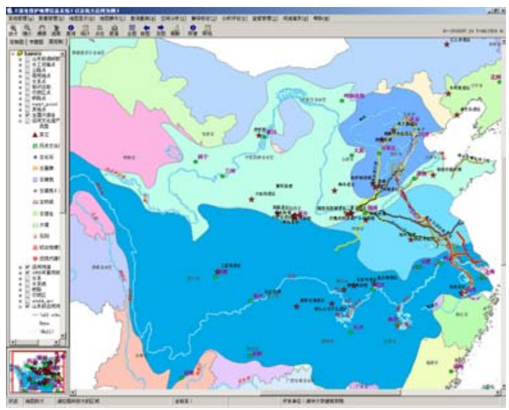

Figure 4. The GIS system for GCC conservation

The GIS system has shown its value in an archaeological extraction approved by government, at Nanwang, Shandong province. With the help of local archaeologists, we utilize the satellite imagery to detect disappearing channels. Moreover the GIS system is used to manage the documents and surveying datasets, visualize the extraction site, and predict potential archaeological site locations.

3.2.2 3D Simulation System of GCC

A 3D simulation system is build to modelling the landscape along GCC, using the data of DEM and SPOT 5, following the methods we have introduced for simulating Jinjiang Basin with special corrections (Huang *et al.*, 2006; Pollefeys *et al.*, 2000). Regarding to the massive data of this project, Oracle 10g is chosen to manage the spatial data and feature attribute, instead of the Microsoft Access. There are two attractive characters of this system. The first one is the multi-scale simulation and modelling, from the large landscape of GCC to a historical site along it; moreover it can be visited from Internet by the same address mentioned above.

Figure 5. Visualization of a historical building in the 3D simulation system

Figure 5 shows a historical building, Shanxi & Shaanxi Proinvincial Guildhall at Liaocheng city，Shandong pronince, build in 1743,Qing dynasty, which has been restricted in the 3D simulation system. Visitors can fly through in that virtual senses freely and enjoy the gorgeous and elaborate building through Internet.

3.3 Related Thematic Researches

3.3.1 Spatial-Temporal evolution of GCC's channels

Combined with historical documents and Chinese traditional atlas on GCC, we endeavour to reveal the spatial-temporal evolutions of GCC with SIT from the time of its building.

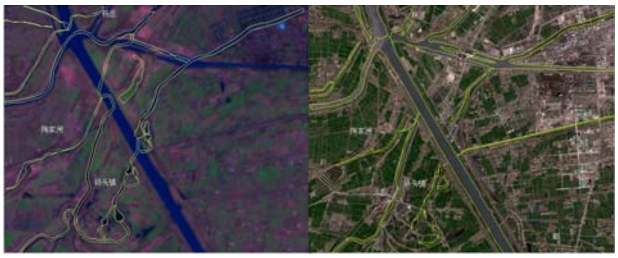

Figure 6. The variation detection of GCC's channels at Qingkou,

Figure 6 shows the evolution of GCC at a crucial node, Qingkou, Huaian city, Jiangsu province, where eight rivers meet and cause obvious changes, including abandoned yellow river and GCC. The lines on the left graphic are channels extracted from air photo in 1954, the base map is TM imagery of 1989 with the resolution of 30m, while the lines on the right graphic are channels in 2000 gained from documents, and the base map is merged SPOT5 imagery of 2006 with the resolution of 2.5m.The result has been accepted by the Journal of Tsinghua University (Science and Technology) and will be published soon.

3.3.2 Land use and land cover changes of important canal cities and some special canal sites

The study of LUCC on GCC regions would reflect close connections between GCC and its surroundings; driving factors of its evolutions from natural perspective as well as socio-economical, and to what level GCC had influenced the development of the canal cities. Figure 7 indicates the case study we have conducted at Yangzhou city, Jiangsu province. Based on imagery in 1954, 1998, and 2002, the study used extraction after classified method to monitor land use changes from 1954 to 2002; while classifying, the object-oriented method was used to extract features in different temporal imagery. The result has been accepted by proceeding Geoinfomatics2008 at Guangzhou city, China, and will be securable soon.

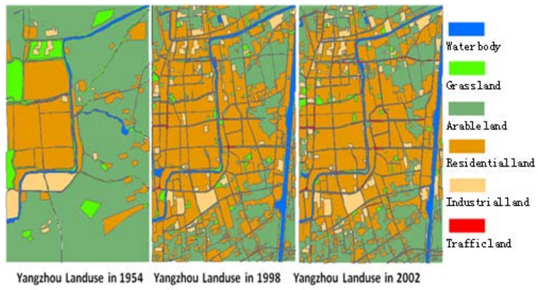

Figure 7. LUCC of Yangzhou, a southern city along GCC

3.3.3 Investigation of cultural resources along GCC

With the support of data collecting system based upon hand-held PDA, professionals of cultural heritage conservation from Beijing city, Tianjin city, Hebei province, Shandong province, Jiangsu province and Zhejiang province carried out field investigations along the GCC. Related data is recorded following the established standards, and then pre-processed data is storied in spatial database and presented with geography information system with designed symbols. Figure 8 shows cultural resources of GCC at Beiwu Lanke districts near Jining city, Shandong province.

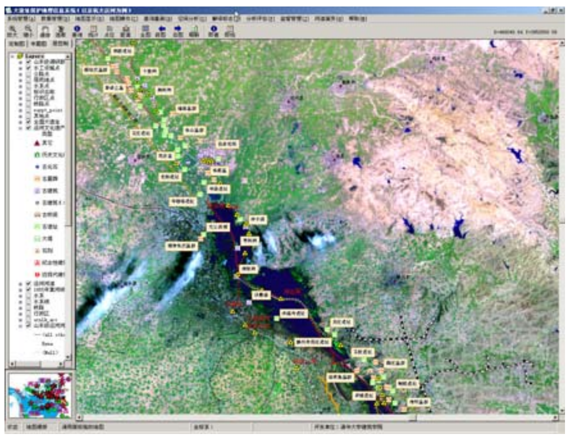

Figure 8. Cultural resources of GCC at Beiwu Lake district near Jining city

4. CONCLUSIONS AND DISCUSSIONS

We have utilized common SIT in the GCC study of investigation and conservation, including GIS, RS, GPS and the visual method, VR. The results indicate that

(1) A framework is brought out for applying SIT to conserve historical cultural heritage in China, which plays as the guideline of our research activities.

(2) Combined with satellite image of high resolution, early panchromatic aerial photography are useful to detect the spatial morphological anomalies of GCC caused by modern construction activities.

(3) Multi-scale, multi-source and multi-temporal data are necessary to investigate and conserve large-scale historical sites with the ability of detect the long evolution trends comprehensively.

(4) This work has explored the evolutional process of GCC at Qingkou district, Huaian city, Shandong province in recent sixty years, which shows the great potential of SIT in the archaeological prospecting.

(5) The satellite image was utilized to probe the LUCC of cities near GCC, aiming to found the connections between cities and GCC, especially in terms of spatial characters. Researchers from the field of archaeology and urban study have argued about the complex relationship between GCC and the cities near by. The ancient status could be only acquired from historical literature, while the current changing process can be obtained from remote imagery.

(6) Handheld PDA with the GPS module was used to assist conservator investigating GCC in several regions, including Beijing city, Tianjin city, Shandong province, Hebei province, Jiansu province, Zhejiang province. From Sep. 2007, those equipments also have been utilized to facilitate 3rd National Cultural Resources Investigation in above regions.

(7) On the basis of this activity further studies have been planned to improve the accuracy of the acquired knowledge to extend it to all known cultural heritages along GCC, and to validate the framework at the new depth, which will then become the reference for conserving large-scale historical sites.

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