Applications and Development of archaeological remote sensing Technology in China

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Abstract: Archaeological remote sensing is the archeological research using remote sensing data as data sources, and at present it is mainly used to investigate the distribution of archaeological sites and predict the existence of above ground or the underground ancient relics and their distribution pattern of detection, the space mapping of the ancient ruins, and the virtual recovery of ancient monuments and their background. Remote sensing technology is able to quickly and efficiently find the distribution of information of ground and underground ancient relics. It plays a significant role in the present archaeological research, and has increasingly become an essential process in large-scale archaeological investigation, especially pre-site inspection. Significant progress has been made in archaeological field investigation due to the rapid development of remote sensing technology, as well as the emerging of the new goals of archeology, the new needs and the applications of remote sensing technology. This article reviews the history of archaeological remote sensing, and introduces the advantages and roles of remote sensing technology in the detection of large-scale sites, and some research instances such as the current archaeological remote sensing and virtual archaeological research, and finally surveys the problems in the development of archaeological remote sensing.

Key words: remote sensing, archeology, grand site

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1 INTRODUCTION

China has a vast territory, and is the only ancient civilization in the world which has a continuous development history of over 5000 years, with many cultural heritages distributed throughout the country, especially those major sites which have great impact on China’s politics, society, military and foreign relations, such as in the 2nd century BC the Silk Road opened up for spreading Chinese civilization to the world from the land and sea. Therefore, it is of great significance for the study of China and the whole history of human development to be fully aware of all kinds of information existed in these valuable cultural heritages.

As a study of the history of human development, archeology came into the world in the western country during the early 19th century, and was introduced into China in the early 20th century. With the development of natural sciences, archeology has developed into environmental archeology, remote sensing archeology, underwater archeology and other multi-disciplinary system from originally single subject. Particularly, by means of combining the humanities and social sciences and the natural science in the theory, methods and techniques, etc., remote sensing archeology extends the scale and depth in archaeological research. Earth observation technology mainly based on remote sensing technology, geographic information systems, global positioning systems and virtual reality technology has become important tools that help us to understand the temporal and spatial distribution pattern of cultural heritage, to reconstruct the development history of ancient civilization, to establish the cultural heritage information management system, and to realize a virtually recovering of ancient civilization.

2 DEVELOPMENT OF ARCHAEOLOGICAL REMOTE SENSING SCIENCE

In 1906 the British general H. P. Sharp used a hot-air balloon to take photograph of the late Neolithic Stonehenge sites in both vertical and slant ways. British geographer and archaeologist O. G. S. Crawford laid the foundation of archaeological aerial photography during the 1920s. He introduced the three marks in the aerial archaeological survey and aerial photo analysis: shadow marks, soils marks and vegetation marks, and identified the ancient Roman ruins from battlefields in the air photographs. A theoretical foundation for archaeological aerial photography was preliminarily established in 1930s, and many countries gradually applied the methods of archaeological aerial photography and got a large number of archaeological aerial...
photos. During World War II, aerial photography technology was further developed, and the vertical and slant photography technology were greatly improved, as well as color film and color infrared film were invented. Since then, archaeological aerial photography in Western Europe began to develop much more rapidly, especially reconstruction and economic development in the post-war when encountering sharp contradictions between economic development and historical heritage preservation, so the great importance was attached to archaeological aerial photography. Through the use of aerial photography and geophysical archaeological non-destructive detection technology, etc., the efforts of the archaeological exploration were strengthened and the cost of large-scale exploration operations was reduced.

In the short period of 15 years from the former Soviet Union satellite successfully launched in 1957 to the United States earth resources satellite which imaged the Earth in 1972, when space technology made a breakthrough in development, archaeological remote sensing opened a new chapter in getting earth observation data because of a large number of satellite platforms. Now we can acquire not only multi-spectral (or hyper-spectral), multi-angle, multi-resolution, multi-scale optical remote sensing data, but also multi-band, multi-polarization and multi-mode imaging radar data; not only the global-scale high-temporal resolution remote sensing images, but also high spatial resolution satellite imagery such as Quickbird with spatial resolution of 61cm. All of these provide a variety of data to the archaeological research including environmental archaeological, archaeological landscapes and cultural, paleoenvironmental reconstruction, and also provide the basis for remote sensing image database to geographic information systems for ancient cultural resource management. Through remote sensing, geographic information systems, global positioning system with a combination of archaeological fieldwork, we can accurately extract the cultural heritage of human history, spatial information, and monitor the temporal and spatial variation of cultural heritage under the human and natural factors, in order to provide a scientific basis for the government departments in the protection of cultural heritage.

Virtual archeology was developed as a new computer-based technology in 1990’s. With the virtual archaeological techniques, people can apply the historical records of cultural sites which have ever been suffered from damage, and combine with the topography, drainage, terrain elevation and other landscape features, to rehabilitate and reconstruct the original appearance of ancient sites, so as to provide historical data which can be archived into computer for heritage preservation.

Internationally, early in 1990 the international academic meeting “space archaeological study” was prepared by the French Space Agency, NASA, ESA, NASA Group agencies and other remote sensing groups. In March 1997, the first “remote sensing archaeological application Conference” was held in Minnesota, the United States The conference discussed the satellite and aerial remote sensing in archeology, archaeological resource management, population and distribution patterns of archaeological and environmental studies to identify the advantages and the important role. In 2001 “Italy - United States Remote Sensing Symposium: the reconstruction of the ancient terrain with digital technology” was organized by the Italian Institute for Cultural Heritage applications and the United States Boston University Archaeological Research Center, Center for Remote Sensing and archaeology department in cooperation with NASA. The symposium mainly aimed at GIS, spatial analysis and remote sensing technologies for the reconstruction of the ancient terrain, as well as evaluated and displayed the archaeological landscape as an important and various cultural resources. In April 2002, the international conference “computer applications and quantitative methods in archeology” was held in Greece under the theme of “archaeology and digital heritage”. The conference discussed the unique function of space information technology in the archaeological application fields, and evaluated and analyzed the results achieved in the World Heritage’s monitoring, management, mapping, and protection with the spatial information. These reflected that the archeological development with themes of digitalization became the mainstream in the development of interdisciplinary. Remote sensing and virtual reality technology have become the main research techniques in archeology and ancient sites protection.

In comparison with the Western countries, China’s development in archaeological aerial photography began late. During the period of the 7th Five-Year Plan, China carried out an archaeological aerial photography for the ancient city of Shouchun in Anhui Province, and the Museum of Chinese History set up an Archaeological Center for Remote Sensing and Aerial Photography. And then they made an aerial photography in Yanshi Erlitou Ruins in Henan Province, rural ditch Yanshi Mall body sites, Luoyang, capital of the Sui and Tang site of the south east and so on. The Shandong Institute of Cultural Relics and Archeology, in cooperation with Prehistoric Archaeological Research Department of Ruhr University in Germany, analyzed the aerial photos located in Linzi County in Shandong Province, acquired by the U.S. military in 1920s—1930s, and mapped the ancient tombs throughout the city and their location, as well as published the first report of archaeological aerial photography. In 2002 China developed another archaeological remote sensing work in northern Shaanxi Tongwancheng and Inner Mongolia part of the ancient sites and Shanhaiguan Great Wall, Mutianyu, Zunyi Hailingtong. In 2006, the “Applications of Spatial Information Technology in the great site protection” project, supported by the Ministry of Science and Technology, was launched to make a comprehensive study on the present situation and the history of the evolution of the Grand Canal of China.

In 1993, Archaeological Remote Sensing of Urban and Environmental Laboratory was approved by the Ministry of Education, set up at East China Normal University, which has been making research on remote sensing archaeology in the lower
reaches of the Yangtze River, Silk Road, the Great Wall, the Central Plains and other areas, and made remarkable achievements (Liu, 1998). The Institute of Geography, Henan Academy of Sciences investigated into the application and experimental study with photogrammetry, photo interpretation of ancient cultural relics and other work in archaeological sites through the combination of remote sensing technology and the archaeological department. Chinese Academy of Social Sciences used archaeological aerial images, satellite images, as well as shallow geophysical methods (ground penetrating radar, etc.) to find the archaeological sites and applied high-resolution non-destructive detection for archaeological relics, providing a reliable basis for the archaeological excavation and research.

And at the same time they developed the projects of “high-reliable basis for the archaeological excavation and research.

Laoshan Tomb of Han Dynasty with high-resolution camera. Data, and additionally delineated the “anomaly” of the Beijing and Ningxia Autonomous Region with the shuttle imaging radar grammetric work and analysis of photography. Anhui Normal University and Anhui Center for Geological Remote Sensing made an archaeological remote sensing research in the Grand Canal of China. Institute of Remote Sensing Applications, Chinese Academy of Sciences, detected the ancient Great Wall buried by dry sand, located at the junction of Shaanxi province and Ningxia Autonomous Region with the shuttle imaging radar data, and additionally delineated the “anomaly” of the Beijing Laoshan Tomb of Han Dynasty with high-resolution camera.

Given the domestic demand for archaeological remote sensing, “Archaeological Remote sensing Laboratory Jointly Sponsored by Chinese Academy of Sciences, Ministry of Education, the State Bureau of Cultural Relics” was set up in November 2001 in Beijing, and the official archaeological remote sensing workstations were established in Zhejiang, Henan, Anhui, Shaanxi, Jiangsu, Inner Mongolia, Yunnan province, respectively. This cross-sector, cross-industry Joint Laboratory of Remote Sensing Archeology takes national needs as the goal, through a broad network of cooperation with local archaeologists and remote sensing departments aiming at promoting the development of archaeological remote sensing. The first national conference on remote sensing archeology was held in Beijing by remote sensing archaeological laboratory in December 2002; “the space awareness of the cultural heritage of mankind” Xiangshan Science symposium was held in 2003; Beijing International Conference on Remote Sensing Archeology held in 2004 made the exchange of spatial information into the application of archaeological science. In April 14, 2005, China and UNESCO signed an agreement at UNESCO headquarters and the content was China will join the open initiative action, which was designed to use space technology to assist in the protection of world cultural heritage. Archaeological Remote Sensing Laboratory Jointly Sponsored by Chinese Academy of Sciences, Ministry of Education, and the State Bureau of Cultural Relics will work with the Argentine Space Agency, the Canadian Space Agency, and the Lebanese Center for Remote Sensing, Morocco Royal Center for Remote Sensing and NASA together to assist the United Nations UNESCO World Heritage monitoring by satellite.

3 ADVANTAGES AND ROLES OF REMOTE SENSING TECHNOLOGY IN DETECTION OF GREAT SITE

3.1 Advantages of remote sensing technology in detection of great site

Compared with traditional archaeological fieldwork, archaeological remote sensing can get a large amount of information, which can not be acquired from the ground-based observations in detection of great sites. The main advantages as follows (Yin & Wang, 2003; Zhao, 2004).

3.1.1 Large scale covering

Remote sensing can access global information on the study area, especially like China’s Great Wall and the Grand Canal, the Silk Road and other larger sites. But ground-based observations can only get a view of the features within the landscape, and can not constitute the overall image. The imaging scale of Remote sensing image has a large range from the Moderate Resolution Imaging Spectrometer and low-resolution scan mode synthetic aperture radar(SAR) obtaining the small-scale regional images, to Quickbird and IKONOS high-resolution remote sensing image for studying the ancient sites in detail.

3.1.2 Large spectral range

People can observe by naked eyes only the visible part of the electromagnetic wave, but remote sensing (including geophysical prospecting techniques) is able to observe and record wide range of spectrum range from the ultraviolet, visible, infrared, thermal infrared, microwave, etc., to the whole range of energy-band electromagnetic waves to detect surface features.

3.1.3 High spatial and temporal resolution

Archaeological fieldwork can only survey the archaeological objects at specified time on the field, but archaeological remote sensing could be used to repeat observations in the high temporal frequency and accumulated the obtained satellite remote sensing data in the study area, to study the archaeological sites, the terrain landscape and the ancient sites with changes over time. In the case of spatial resolution, the high-resolution commercial satellite is able to provide multi-band remote sensing images compared to the images obtained by aerial photogrammetry.

3.1.4 High spectral resolution

Multi-spectral remote sensing images can provide different spectral remote sensing information in the same study area, and hyperspectral imager can subdivide from a few dozen to hundreds of sub-bands within a specific spectral range, enhancing
the ability of features (such as crops changes in archaeological study area) recognition.

3.1.5 Penetrating ability

Synthetic aperture radar (SAR) imaging has the properties of penetrating, which can be used for studies of paleoenvironment in arid desert area. And more importantly using ground-penetrating radar technology can obtain the archaeological information in a certain depth under the surface.

3.1.6 Non-destructive detection for archaeological sites

With the advantages of non-destructive detection on the archaeological objects of remote sensing archaeology, using geophysical methods to detect and study the characteristics of sites of shape and pattern of the structure, we do not have to dig large areas, which can save lots of manpower, material and time without any damage to the sites.

3.2 Roles of remote sensing technology to detect the archaeological sites

3.2.1 Important discoveries of sites using remote sensing technology

As the ancient ruins preserved in the surface or under the surface gradually fell into disrepair and loss with the years, some have been turned into farmland, or villages and towns. However, because all these relics were artificially built, there is a difference between these relics and the soil environment around these relics which has not been disturbed by human, which formed a set of special signs on the soil, moisture, surface temperature in the region. Although we can not find even a little special features observed on the ground, these differences would caused spectral differences in the remote sensing images, so these ancient sites can be identified.

In addition, radar has capability of observing and imaging throughout the day, all-weather and penetrating some features under the surface; therefore, the ancient site can be identified from the radar images because of the backscattering characteristics determined by their features. So far, there are many instances of finding ancient sites by using remote sensing technology, which fully reflect the role of remote sensing in the archeological application. Archaeologists in the United States have found ancient Egyptian and renowned Alexandria which have long been sunk at the seabed for a few thousand years by means of satellite remote sensing images. Europe discovered a number of architectural monuments of ancient Rome and the famous “Roman Road” based on early photographs of archaeologists. Scientists in NASA Ames Research Center used remote sensing technology to open the secrets about the Boom Rise and Fall of the Mayan civilization, and successfully identified the characteristics of the ancient Mayan ruins. Greek archaeologists found the ancient city “Helike” in the Collins Bay destroyed by an earthquake in BC 373 by using infrared photograph. NASA archaeologist identified the ancient path in Costa Rica forests from color infrared aerial photographs. In 1994 the SIR-C/X-SAR and AIRSAR imaging radar were made research on the ancient city Angkor in Cambodia surrounded with the thick forest. The distribution of the ancient city Angkor was reconstructed, which expended from original 200—400km² to 1,000km², and the Grand Canal water system was redrawn, so that we know the original appearance of the spectacular ancient city Angkor which has already been dead.

3.2.2 The advantages of remote sensing technology in Large-scale sites investigation, protection and monitoring

China’s cultural relics distribute all around the country, including 38 World Heritages, and a large number of the ancient sites needing to be identified and protected, such as large-scale ancient villages, cities, imperial tombs, canals, the Great Wall, Silk Road. China has more than 1200 state-level key Cultural Relic protection units and 99 national historic renowned cities. It is no doubt that remote sensing technology would be an effective means to explore the ancient sites, and dynamically monitor the changes in historical and cultural sites and ancient ruins. Taking the Great Wall as an example, the entire length of Great Wall is more than 7000 km ranging from Dandong Hushan to Jiayuguan. The ecological environment along the Great Wall became gradually deteriorated, and the Great Wall often suffered from kinds of severe damage due to human factors, especially in the western arid desert area, where the majority of the Great Wall were buried in sand. At present, less than one-third of the Great Wall has been well restored and protected, and another one-third is incomplete, as well as the third did not exist long before. Therefore, it is important to ascertain the distribution of the Great Wall by and better protect the Great Wall by using remote sensing techniques. Silk Road was a main way to exchange China’s culture with the West, and many Chinese and foreign cultural relics were left on this road, such as the ancient cities Niya, Loulan in China, and the ancient city Merv in Turkmenistan Central Asia. Silk Road archaeological remote sensing was an important issue when the shuttle imaging radar passed by China’s ancient city Niya in 1994, and researchers from Canada and other countries carried on a multi-disciplinary archaeological remote sensing investigation into the city Merv that was ever an oasis. They used GPS technology and IKONOS images of the ancient city to locate precisely and analyze ancient ruins. In addition, recently, scientists in China made several remote sensing archaeology researches on the Qin Shi Huang Mausoleum, Sanxingdui, and the Grand Canal. In summary, people may have a better understanding on cultural sites by this work.

3.2.3 Paleoenvironment research with spatial information application

The restoration of the ancient environment played a significant role for the study of social, cultural, economic, natural and geographical conditions, etc. And the changes of palaeoenvironment were also important to research about the ancient environment and political evolution. Using remote sensing to study the long period changes of environmental history mainly depended on these “signs” showed on remote sensing images to be identified. Due to a variety of research subjects have their own characteristics which were different from each other, many
of which got reserved in different degree. These characteristics were reflected in the remote sensing images, and you could identify them by the differences from the color, shadow, shape, size, texture, etc. (Liu & Wang, 2006; Wan & Zhou, 2007).

Currently, the application of remote sensing techniques for environmental archeology, mainly focused on the use of multi-temporal, multi-source and multi-resolution airborne and space remote sensing images to monitor environment of archeological sites, landscape archeology, environmental change and relationship research of social transformation and historical periods environmental restoration.

The space shuttle Columbia that carrying the SIR-A radar flight in the eastern Sahara Desert in November 1981, and McCauley et al. studied the radar echo on the SIR-A images from bedrock under the sand, which revealed an ancient river several meters below the sand layer. The study showed that: the northern part of Africa had a much larger stream system than today’s Nile river, which denied the deduction that there was no trunk stream of water system. The paleochannel provided an oasis in the desert for Paleolithic humans, and showed the environmental conditions at that time in the Sahara desert. Combining multi-source satellite remote sensing data and validating the data by field work in Xinjiang at several times, researchers from the Institute of Remote Sensing Applications, Chinese Academy of Sciences, revealed the existence of ancient water system in the region. They found that sand path flow from the southwest to the northeast and then into the Yamaileike desert. Using the old aerial photo taken in the 1950s, the watershed tanks of the Grand Canal was discovered, which disappeared in Nanwang, Jining, Shandong province, and the work provided important reference for the protection and arrangement of the heritage sites.

3.2.4 Non-destructive detection to underground sites

Another study in remote sensing archaeology is the non-destructive detection of archaeological sites buried under the ground. Current non-destructive detection methods include magnetic detection, resistance probe method, microwave pulses “ground-penetrating radar” as well as seismic detection, etc.

China starts this work very late, and the main results contain the detection of “Yin mountain large tomb” located in Shaoxing, Zhejiang province with ground-penetrating radar by East China Normal University. The First Qin Emperor Mausoleum was explored using more than 20 advanced high-precision physics detection technology such as the airborne remote sensing hyperspectral technology, thermal infrared remote sensing technology, magnetic technology and electrical technology. The First Qin Emperor hill covered 2.13 km².

Internationally, Israel expert made use of thermal infrared sensor in the 1333m altitude of the Golan Heights, and succeeded in detecting the archaeological sites buried under the soil and mapping with thermal infrared. This is the first archeological work with thermal infrared remote sensing.

3.2.5 Archaeological thematic mapping and Cultural Relics information system

The main tool for remote sensing archaeology are remote sensing images, because image itself can be preserved for long time. We can discover the damaged relics on the previously archived remote sensing image, discover the current relics in the current image, and make the archaeological information thematic map. The location, region and true appearance features of these relics could be stored for future analysis.

After geometric correction, remote sensing images have very high accuracy, and we can directly measure the area and shape of the archaeological sites. Besides, we can directly draw these results onto the map, so this will be very meaningful.

At present, internationally, using remote sensing for archeological mapping is the main part of archaeological remote sensing, and is developing rapidly and widely. Especially, high-resolution satellite images and aerial photographs are the main data source of the large-scale mapping. Remote sensing and GIS technology are applied to survey large-scale site and position precisely, to provide environmental monitoring, site positioning, and forecasting purposes for future.

There are a variety of applications with GIS in archeological research. GIS can be applied to data collection and storage, analysis, interpretation and expression. Specifically, it can be summarized as the following aspects: establishing the archeological information management system, establishing prediction model of archaeological sites, development and expansion of archaeological sites, landscape archeological GIS research, etc.

3.2.6 Space technology and ancient human remains and environmental reconstruction

Since the 1990s, there has been a virtual heritage (or virtual archaeological) technology, which refers to the use of advanced computer technology applied to do research on world history, culture, natural heritage protection and development. Virtual reality technology is a key technology for the development of its application.

Virtual reality is selected as the technical support to research on virtual heritage, because the information what the virtual heritage want to express is multidimensional, not only historical authenticity, but also a cultural art, and the reality of the environment. And according to the current computer technology, it is necessary for the expression of multi-dimensional information to provide high-performance hardware of virtual reality technology to support. Studying virtual heritage also involves other types of computer technology, such as the scanning technology, information processing, computer-aided design, geographic information systems, etc. The selection of technologies in specific applications should depend on the research project. From the concept, virtual heritage is to emphasize the cultural realities of history that we will express, so it reflected the efforts made to create science and art and continuous upgrading knowledge, beliefs and values experience in the development of human. Virtual heritage is the new direction of development and trends to foreign history heritage protection and more and
more people are engaged in studying this field. China is a country with a long history of ancient civilization, and its rich historical and cultural heritages of the history have become an important part of cultural heritage of the world. Virtual heritage studies can promote heritage conservation and development of China’s historical and cultural heritage, and adapt to the trend of development of the world. At the same time it is of great significance for improving China’s status in the world historical and cultural heritage.

Virtual heritage technology can be used in reconstruction of historical and cultural sites. Demonstration of the British Museum’s ancient Greek temples, the ancient Roman castle shown in the Los Angeles Museum of the United States, are based on defective parts to “repair” and simulate. The Digital Dunhuang Grottoes and the digital Imperial Palace were put into practice. American scholar resume virtually the place of New Mexico Indian indigenous people. Egypt scholars also conducted a virtual simulation with a large pyramid in different angles. Japanese scholars simulated the historical site located in Pengtou mountain, Hunan Province, China, during the rice culture 7000 years ago with virtual reality technology combining with spatial information, represented the scene of urban layout. We can also use virtual technology to restore the original appearance of the disappeared city (such as the ancient Loulan city, the Grand Canal and the ancient river channels), and simulate the current sites with virtual reality at the same time, in order to provide a valuable electronic data for heritage sector.

4 EXAMPLES OF WORK ON ARCHAEOLOGICAL REMOTE SENSING

In recent years, with the growth of China’s economic strength and the improvement of application level of remote sensing technology, the field of application of remote sensing being broadened and national emphasis on remote sensing archaeology, archaeological remote sensing technology in China has improved continuously, and remote sensing technology in archaeological sector has more and more been put into practice and achieved a great deal of research results. The following is the examples and part of results obtained by the Joint Laboratory of Archaeological Remote Sensing in recent years.

4.1 Remote sensing archaeology

4.1.1 Grand Canal of China

Grand Canal of China, as a great works created by the Chinese ancient people, is a valuable cultural heritage left to the world by Chinese nation. In recent years, the plan that Grand Canal of China applies for world cultural heritage has been made under the efforts from cultural relics departments, relevant experts and others. As a result of the large-span of the canal, as well as the diversity of the cultural heritage of the canal, remote sensing technology was applied first of all to the Grand Canal of 1794 km, and the research was developed on the surrounding environment today and historical evolution, in order to provide a scientific basis for making a protection plan.

The changes of the canal and the canal city’s environment within the 60 years can be drawn by processing and analyzing different time, different-resolution remote sensing images. Fig. 1 shows the areas flowed through by the Grand Canal and distribution of SPOT5 data acquisition, Fig. 2, Fig. 3 and Fig. 4 show the effect of the three regions along the canal route compared air photos with satellite images.

![Fig. 1 SPOT5 images distribution along the Grand Canal of China](image)

4.1.2 Great Wall

China’s Great Wall is one of the greatest works in the history of human civilization. It was built more than 2000 years ago during the Spring Autumn Dynasty, War Times Dynasty, and the Qin Dynasty after the unification of China. Han and Ming Dynasties also made large-scale construction.

People wanted to know the specific length, location and spatial distribution of the Great Wall for a long time. However, due to the span of the Great Wall’s distribution, the complex topography, and even burying in some areas, it is difficult to arrive at a unified conclusion about these information. Therefore, State Administration of Cultural Heritage planed to apply remote sensing technology to conduct a comprehensive survey on the Great Wall. Prior to this, China’s science and technology workers also made use of remote sensing to detect and explore the Great Wall’s distribution, of which the excellent work is done by Guo H D (1997), who used multi-band, full-polarization imaging radar SIR-C to identify the ancient Great Wall buried in dry sand in Sui and Ming dynasties located at the junction of Ningxia and Shaanxi province (Fig.5), as well as analyzed the changes of environment and identify Shanhaiguan old dragon head of the Great Wall with high-resolution remote sensing image QUICKBIRD and other images (Fig. 6).
4.1.3 Archaeological Sites of Ancient City in Inner Mongolia

There are various cultural sites in Inner Mongolia, but Inner Mongolia has the vast territory and many sites are located in desert, grassland, and no man’s land. With ground survey methods to investigate these sites, it is much difficult to achieve a well comprehensive investigated effect throughout the Inner Mongolia. In 2002, by use of Lanying AD-200 light aircraft manufactured by Beijing Keyuan Light Aircraft Industrial Co., Ltd, the sites located in the central and northern Shaanxi, Inner Mongolia Autonomous Region were observed and investigated, and good results were achieved. The aircraft structure is relatively simple with small size and light weight, so it can facilitate rapid disassembly, and you can transport it with ordinary trucks. At the same time, the requirements of flying and landing is pretty low that it can be operated on roads or flat grass, etc. Besides, it requires relatively short runway. Therefore, using such plane brought great convenience to investigate the sites. Fig. 7 (a) is the AD-200 light aircraft, Fig. 7 (b), Fig. 7 (c) is the photography taken by aerial digital camera in 2002, and a group of Juyan sites was found in Inner Mongolia. AD-200
4.2 Virtual reality

Through the combination of spatial information technology and VR technology, the spatial geographic information of the large-scale ancient sites and visualization expression of cultural information in various environments, network, and integration management were realized. This technology provides a much more natural, convenient, and efficient tool to express spatial information. The platform “large sites virtual reality system” which has the characteristic of three-dimensional dynamic,
Fig. 6  Shanhai guan Great Wall old dragon head in QUICKBIRD image

Fig. 7  AD-200 light plane and groups of sites in Inner Mongolia Juyan photoed by airborne digital camera

Fig. 8  The new sites in Inner Mongolia found by AD-200 light plane in 2005
(a) and (c) Great Wall; (b) Qing straight road; (d) unnamed Great Wall
Several works in using virtual reality technology to protect large archaeological sites as following:

(1) Virtual reality technology for large archaeological sites.

We have completed the research work about three-dimensional information acquisition methods and data structures, etc. In large archaeological sites, three-dimensional visualization process of a large-scale digital terrain has been realized; simulation methods of the evolution process of a great site have been studied, researches on generation of dynamic body of water have been carried out.

(2) The development of three-dimensional simulation of the scene: such as virtual reality scenario of Beijing’s Tongzhou, Shandong’ Nanwang, the ancient city of Yangzhou (Fig. 10, Fig. 11). We have achieved a single version of the multi-level integration and management scene. A network of three-dimensional scenes of the Active X control can be achieved in small three-dimensional Web browser scene.

(3) The Server/Client system was developed based on Microsoft DNA, and the Server/Client program to view three-dimensional information, which is being tested.

(4) Integration and hierarchical block processing of ETM,
SPOT5 data have been made. The $1 : 250,000$, $1 : 50,000$ DEM model were finished. The virtual reality visualization system has been established to combine with the remote sensing images covering the entire canal and relative China’s eastern region.

5 SOME PROBLEMS FACED BY REMOTE SENSING TECHNOLOGY IN THE STUDY OF HISTORICAL SITES PROTECTION

Remote sensing technology with its unique advantages plays an increasingly important role in the detection and protection of large sites. However, there is still a gap when compared with other application fields.

(1) Archaeological remote sensing is the mutual penetration science of natural and social sciences. It requires that remote sensing scientists must have the technical knowledge and the history archaeological knowledge.

(2) The complexity and diversity from the natural environment, particularly strong noise in the human activity areas, will bring much difficulty to extract useful remote sensing information in the archaeological sites.

(3) The archaeological sites in different times, different areas, even in the same time, the same area, are different from the structure to the material composition. And the relevant theoretical researches such as the mechanism of the interaction between electromagnetic waves with the sites still need more work.

(4) The existence condition of most large-scale ancient ruins is semi-buried or buried. How to extract information from the complex weak features is the key technology problem to solve at present.

(5) Remote sensing archaeology is a cross-subjects and in-
terdisciplinary science. In the study of archaeological sites, it is necessary for remote sensing scientists to integrate the knowledge of archeology, environment, geophysical exploration, drilling and other means and methods.

Remote sensing technology has demonstrated great application potential in the study of sites. With the continuous development and improvement of remote sensing technology and the deepening of archaeological research with archaeological remote sensing, like other applications, remote sensing will be continuously improved and upgraded in the application in archaeological work, and contribute to the exploration of the origin of the Chinese civilization and the protection of important sites.

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摘　要：

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1906 H. P. 61cm

2 　　

1906 O. G. S. 1957 1972

E-mail: nieyp@irsa.ac.cn
3.1  Quickbird® 1KONOS® 400km², 2003; SIR-C/X-SAR®, AIRSAR® 2004): 3.1.2  3.1.3  3.1.4  3.1.5  3.1.6  3.2  3.2.1  "Helike"; 3.2.2  200—400km²  1000km²,  373  1994  38  1200  99  7000km
3.2.3 SIR-A 1981

11. Merv, McCauley

SIR-A 1994

GPS, IKONOS

3.2.4 2.13km², 56.25km²

3.2.5 GIS, 2005

3.2.6 GIS, 2007
4.1 (a) 2005, (b) 1954
4.1.3 AD-200

SIR-C

Quickbird

2002

2005

2002

2005

2005

2005
4.2
(1) (simulation)

(2)

(3) Microsoft DNA Server/Client

(4) ETM SPOT5 1:25

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