The Application of GIS in Remote Sensing and Aerial Archaeology

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Precis: The remote sensing and aerial archaeology, due to its special characteristics, has always been dependent on the basic theory and attainments of geographical information system (GIS). GIS played a decisive role in the archaeological survey, ground localization through ground positioning survey (GPS) and space calculation and analysis when a large ancient site in the middle and eastern part of Inner Mongolia was explored. This event has provided many valuable experiences and enlightenment to archaeologists and computer experts as well.

1. Foreword

Remote sensing and aerial archaeology is a new frontier science, which has been gradually developed on the basis of modern archaeology and modern science and technology. In the course of worldwide large-scale land exploitation and social development, not only were the environment and natural resources severely devastated, but also the historical relics buried under the ground and cultural sites on the ground were damaged to a certain extent. Confronting such a serious situation, all the relics-protection organizations and archaeologists all over the world have been seeking an advanced and convenient macroscopic method for relics protection and archaeological research to offset the present backward relic-protection administration and out-of-date methods of archaeological research. The emergence and development of remote sensing and aerial archaeology are the inevitable results of their common efforts.

Remote sensing and aerial archaeology is a science, in which sensors are used from a high altitude in space to survey and probe the relics and cultural ruins on the surface of the earth through photos. These photos are received by ground stations and analyzed through application processing system. To accomplish the analysis and study of these complicated photos, topographic maps and data, GIS, which is fashionable throughout the world, is a necessary tool for archaeologists.

From 1998 to 1999, we carried out remote sensing and aerial archaeological survey over a large area of ancient ruins and historical sites in the middle and eastern part

of Inner Mongolia. The data obtained from the survey were studied and analyzed with the help of GIS. This was the first time for Chinese archaeologists to use the imported technology of GIS in their scientific research and it is of great importance.

2. A Brief Account of the Area Surveyed

The following historical sites and ruins were surveyed with the remote sensing and aerial archaeological method and probed on the ground: ruins of Shangdu (Upper Capital) of the Yuan Dynasty (1271-1368), Shilangcheng, Zhenzishan, Yikeshu (a Yuan Dynasty cemetery) and Yangqunmiao (a site of sacrifices to God or ancestors in Yuan Dynasty) in Zhenglan Qi, Xilinguole League (Xilin Gol); Liao Dynasty's (916-1125) Shangjing, Zhongjing, Zuzhou, Zuling, Qingzhou, Qingling and the sites of Qianzhao and Houzhao grotto temples, Jin Dynasty's (1115-1234) border castles and ditches and Han Dynasty's (206BC-220AD) Heichengzi in Chifeng City; as well as Xiajiadian low-level cultural village sites and mountain cities in Yinjiadian, Jifangyingzi and Sanzuodian along the banks of the Yin River. The total area surveyed was around 100,000 square kilometers.

3. The Procedure and Method of the Research Work

1) Establishment of information sources

What is of the first importance for archaeological research and GIS basic theoretical analysis is the collection, accumulation and methodical storage of a large quantity of basic data. So first of all, we established our information sources and gradually upgraded them.

Our initial and tentative information sources consisted of the historical documentary materials, aerial and satellite photos at hand, large-scale (larger than 1:5000) photos especially shot for archaeological use and various maps and topographic maps.

In order to acquire a large amount of accurate data of ground control points (GCP) to calibrate aerial photos, we carried out an overall ground positioning survey (GPS) on the ancient ruins and historical sites.

To guarantee the accuracy of the data, we developed three application programmes by making use of Microsoft Visual Basic: programme for collecting GPS data, draft-making programme for practical survey and programme for initially setting up GCP data bank.

(1) Collection of GPS data: Since GPS data-collecting programme has been created by using the technology of data base, the programme can identify the GPS output in NMEA-0183 data format. GPS equipment and computer communication adopt RS232, from which information about the longitude, latitude, altitude and the situation of the receiving satellite can be obtained and the collecting time interval can be adjusted (the precision of

data registered depends on the accuracy range of the GPS equipment and in our practical work, a GPS equipment of Garmin GPSMAP 196 was used).

(2) ESRI Map Object is used as the basic controller in the drafting programme. By using the technology of data base, outlines of the sites or ruins on the ground were drafted according to the ground coordinate points provided by manual input or the data base, so as to inquire into their relative positions and their rough shapes.

(3) The installation of GCP data base, which can record data in the course of the survey and put them under unified control, is the core of our system. The whole data bank contains the following data sheets and main fields: dates, number of the film, number of the aerial photo, location, records of the survey, number topographic map size, number of the ruin or site, name of surveyor, name of photographer, name of editor, aerial photo save path, processing aerial photo save path, sketch, number of GCP point, GPS-GCP block data (longitude and latitude) and GPS-GCP block data (ground coordinates).

2) Later stage processing of pictures and data

To decipher the aerial photos further and make maps, ERDAS Imagine was used to process the photos after a data source was obtained. The procedure is shown in Picture One.

(1) Necessary equipment

A) A scanner of UMAX Mirage II 24/36 bit is used with optical resolving power of 700-1400 dpi (Its largest resolving power can reach 4800-9600 dpi after software interpolation processing.) Its largest scanning area is 290*432mm.

B) The drawing instrument is HP Design Jet 2500cp, a color thermorelay ink spray printer with picture size of AO width and a resolving power of 600-600 dpi.

(2) Usage of the equipment: Considering the capacity of the system and to guarantee the best quality of the images (or films) scanned and output effect, the scanner adopts 1400 dpi, 24 bit pattern with the output in TIFF format; the output of the drawing instrument adopts 600-600 dpi fine pattern.

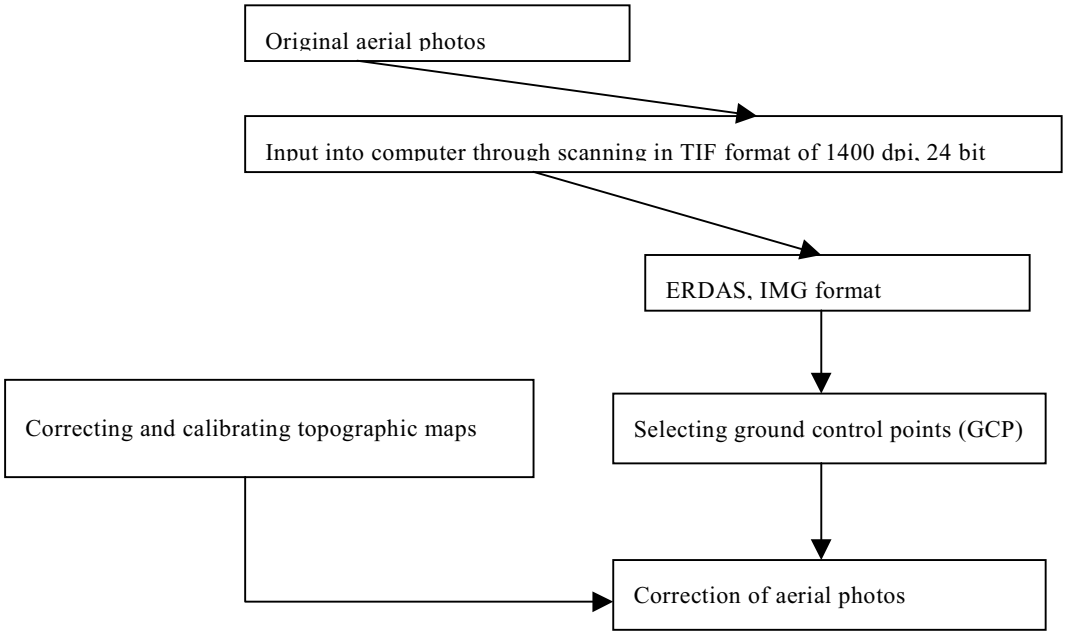
To satisfy the concrete requirements of archaeological research, the aerial images were processed in the following aspects:

(1) Clarification of images

Using the function provided in View of ERDAS Imagine, the images were sharpened and adjusted in color and contrast to increase clarity.

(2) Correction of aerial photos

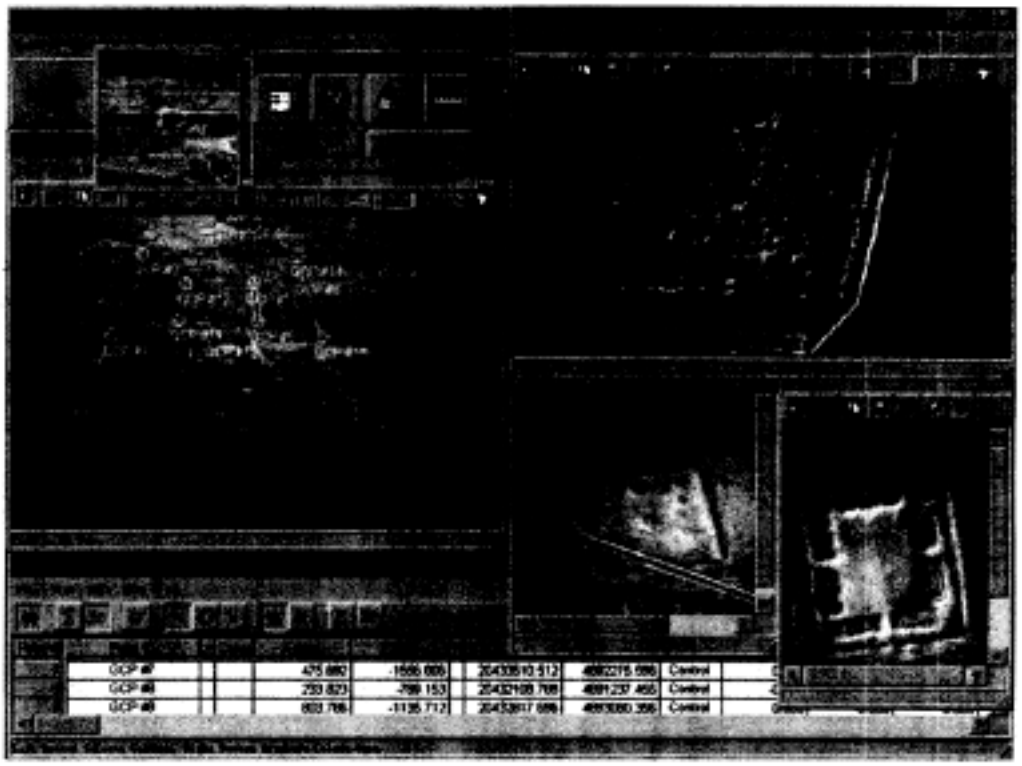
Making use of the function of Geometric Correction provided by ERDAS Imagine and picking up GPS-GCP block data from GCP data bank, we can correct the images. The corrected aerial photos possess geographic coordinates and projection information.



Picture One – Image processing flow chart

(3) Piecing images together

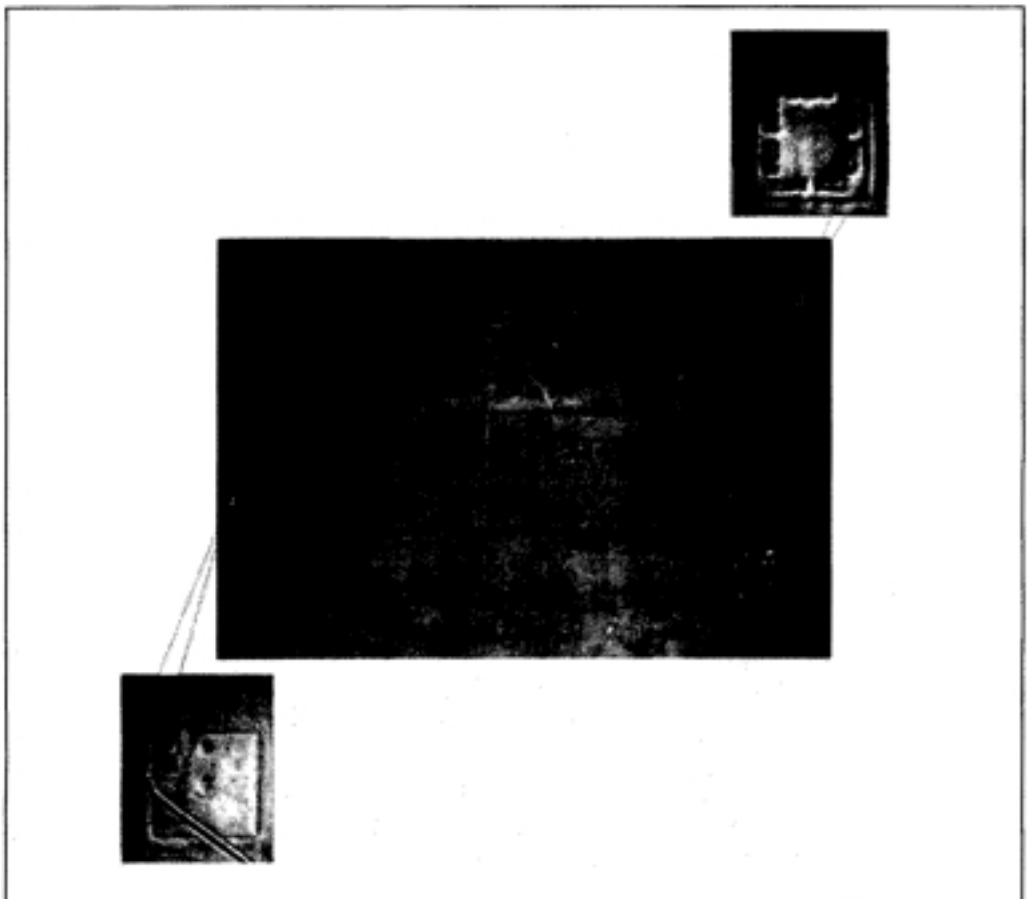
As aerial photography has limitations in angle and altitude, it is difficult to take photos of the complete structure of a historical site covering a large area. Even if a complete image of an ancient site is taken, the images of buildings in it are blurred. As ERDAS Imagine has the function of Mosaic Images, this problem can be solved.



Picture Two -- Procedure of calibrating photos

For instance, in making the thematic picture of Yuan Dynasty's Shangdu, the outline pictures of the whole city including outer city walls (See A, Picture Two), the palace city inside it (See B, Picture Two), east granary (See C, Picture Two) and west granary (See D, Picture Two) were mosaicked into a large picture.

We first calibrated the outline picture of the whole city including outer city walls, then calibrated the palace city according to the calibrated picture of the whole city. After the pictures of east granary and west granary were calibrated, the four pictures were pieced together. In this way, the buildings in the palace city were clearly discernible in the picture and the relative positions of the east and west granaries against the city walls were clearly shown (See Picture Three).



Picture Three -- The site of Shangdu of the Yuan Dynasty

(4) Sketching the contours of interesting areas

For the purpose of further study, we can sketch the contours of city walls or buildings on the pictures. At the same time, we can add vector layers to the pictures to provide conveniences if the pictures are discussed. For example, in the thematic picture of the Liao Dynasty's Shangjing (See Picture Four), we drew outlines of the existing city walls in the sites of the Imperial City and Han City of the Liao Dynasty with the aerial photos as references. We also drew the city walls, which have long been out of repair and damaged by floods, with different marks and legends.

(5) Drawing thematic pictures

A thematic picture is not complete until we calibrate and mosaic the aerial photos, draw outlines of interesting areas on it, mark out geographic coordinates and add surveying scales, compass, legend and caption to it.

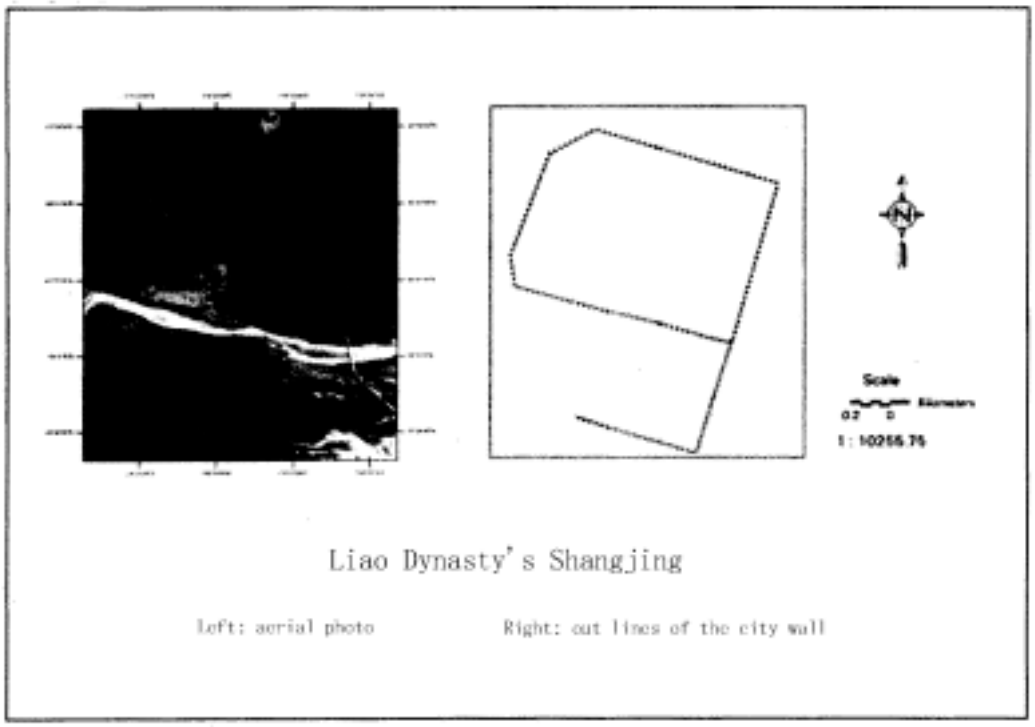
(6) Processing pictures for storing

Directory structure and file style are adopted in the course of processing pictures for storing (For pictures, the common TIFF format and special IMG format of ERDAS

Imagine are used). Important pictures can be transformed into JPEG files, which are logged in GCP data bank as sketches used for picture data retrieval. In this way, a large amount of numerical pictures can be stored in order.

4. Analysis on the Result

The site of Yuan Dynasty's Shangdu is situated in Zhenlan Qi (Banner), Xilinguole League of Inner Mongolia. Shangdu was built in the middle of the 13th century. It was the second largest political, military, economic and cultural center of the Yuan Dynasty just next to Dadu, the capital. As the calibrated aerial photos display a lot of information including geographic coordinates and surveying scales, we can acquire much material from them, which we cannot obtain with traditional archaeological methods. We can see clearly from the photos that the site of Shangdu is square in shape. It is composed of three parts -- the palace city, the inner city and the outer city. The layout of the city is well plotted with streets and buildings orderly arranged. The Shandian River zigzagged by its southern suburb and flood-control dams and water channels could be discerned in the northern suburb of the city. It was obvious that a meticulous overall plan was made before the city was built.



Picture Four -- The thematic picture depicting the site of Liao Dynasty's Shangjing

The site of Shangjing of the Liao Dynasty is located in Balin Zuoqi, Chifeng City of Inner Mongolia. It was built in the early 10th century. The city was divided into two sections -- the Imperial City and the Han City. The Imperial City, situated in the north,

was a region with residences of the Khitan rulers, while on the south of the Imperial City, Han City, which was built later than the Imperial City, was an area inhabited by Han, Bohai, Huihe and other nationalities. The Imperial City is well preserved, whereas the Han City is dwindled into a section of the city's southern wall with the rest washed away by river floods. We have successfully restored the overall image of Shangjing, clarifying many confused ideas about the city with the help of calibrated photos, historical documents and archaeological research (See Picture Four).

5. Prospect

The remote sensing and aerial archaeology with geographic information system (GIS) as its main content has provided archaeologists with an easy and convenient research method, which also plays an important role in relics administration and making plans to protect them. As early as a few years ago, the United Nations Education, Science and Culture Organization (UNESCO) already began to hold training courses all over the world on GIS city planning, protection and administration of world's cultural relics and environmental supervision for famous historical and cultural cities. In active cooperation with the experts of computer, remote sensing and topography at home and abroad, the Remote Sensing and Aerial Archaeology Center under the Chinese Historical Museum is now working on an “Archaeological Information System” (AIS), which will meet the needs of Chinese relics protection and administration and archaeological research. We will collect information and data on archaeological research and historical sites as much as possible and establish an archaeological data bank, which stores vector maps, ancient sites' plans and other image materials to provide scientific basis for relic protection and administration. This center will exchange information and experiences with the international archaeological organizations on the Internet and provide foreign archaeologists with full and accurate materials, making use of the modernized means.

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