A Reconstruction and Representation System for 3D Digital Archaeological Documentation – A Case Study of *Dahecun* Archaeological Site in China

XIAO Jinliang[1], SHANG Jin[1], GAO Ming[1], ZHANG Jianhua[2] and LI Jianhe[2]

[1] Department of Architecture and Urban Heritage, Tsinghua Urban Planning & Design Institute (THUPDI), Beijing, China
[2] *Dahecun* Archaeological Museum, Henan, China

Resumen

En Dahecun, un famoso sitio arqueológico en China, los estratos culturales se han acumulado durante 3.300 años hasta alcanzar los 12,5 metros de altura. Con el fin de mejorar la precisión y la comodidad de los trabajos arqueológicos, ha sido diseñado un sistema digital de representación y reconstrucción arqueológica 3D como herramienta de apoyo de los trabajos arqueológicos y la posterior investigación y representación y reconstrucción virtual de la información del sitio y resultados de la investigación. El sistema beneficiará a arqueólogos e investigadores, así como a la población en general, facilitando el acceso a la información arqueológica.

Palabras Clave*: DAHECUN SITIO ARQUEOLÓGICO, ARQUEOLOGÍA VIRTUAL, REPRESENTACIÓN DIGITAL*

Abstract

In Dahecun*, a famous archaeological site in China, the cultural strata have accumulated up to 12.5 meters, including archaeological remains covering 3,300 years. In order to improve the precision and convenience of archaeological work, a digitally aided 3D archaeological reconstruction and representation system is designed for the support of archaeological work and subsequent research and virtual reconstruction and representation of immediate site information and research output. The system shall benefit archaeologists and researchers as well as the general population with easy access to archaeological information.*

Key words*:* DAHECUN *ARCHAEOLOGICAL SITE, VIRTUAL ARCHAEOLOGY, DIGITAL REPRESENTATION*

1. General Introduction of the Archaeological Site

Dahecun (literally, Village of the Great River) archaeological site is located to the northeastern suburb of *Zhengzhou* City, *Henan* Province, China, which is consisted of 4 different periods of prehistoric settlement sites, namely that of *Yangshao* Culture, *Longshan* Culture, *Xia* Culture, and *Shang* Culture. The archaeological sites date back to 6,800 to 3,500 years ago, with a total area of over 400,000 square meters. The site was discovered in 1964, and excavated 21 times during 1972 to 1987. From the excavated area of 5,000 square meters, 47 building foundations, 297 pits, 354 tombs, 2 ditches[1] were found as well as 3,500 relics made of terra cotta, stone, bone, clam, horn and jade and more than 20,000 specimens.

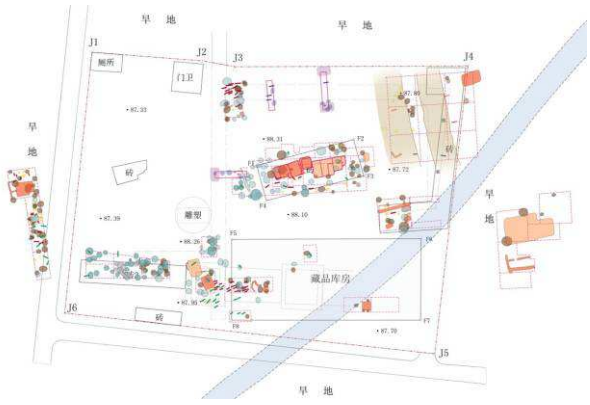

Figure 1. Excavated Area of Dahecun *Archaeological Site, Henan, China*

[1] Most of them backfilled for preservation after documentation.

The huge area, deep cultural strata, rich cultural content and long timespan of *Dahecun* archaeological site makes it outstanding among the thousands of archaeological sites along the Yellow River. The various kinds of excavated settlement up to now, complete in shape with a clear layout of divided function, distinctly reveal the plan of the villages over 3 millenia.

2. Current State of Field Archaeology

There is an integrated procedure for field archaeology in China, with detailed prescription for the arrangement of trial pits, excavation, documentation and its publication. This systematic and scientific methodology puts the archaeology in China on the high level. Only now has some weakness shown.

As the conservation of "Large Archaeological Site"[2] progresses and the introduction of the concept of "Archaeological Park"[3], archaeological work has to be actively engaged with cultural heritage conservation and open representation. This is also a process to elevate the accuracy in field archaeology.

Taken *Dahecun* as an example, an agenda is developed according to the conservation plan to gradually build "*Dahecun* Archaeological Park" from now on. The subsequent work requires the following information: the original state of archaeological site when excavated, the exact spatial position (depth included) of different sites, and the reconstructed life scenes based on archaeological remains. However, existing document is insufficient to satisfy the above needs for the following reasons:

a) Only photos and hand drawings are availalbe, which are not accurate and immediate enough to capture the original conditions of the sites;

b) There is discrepancy in hand drawn site plans, and paper drawings cannot automatically match modern specifications of digital format;

c) Hand drawn sections are relatively few in number, and delibrately chosen by people while more is needed for the conservation and digitized representation;

d) Accurate depth data not available;

e) There are only hypotheses for original life scenes, without visual outputs ready for use.

These deficiencies are in part due to technical limitations in the past, and in part constrained by budget. For example, measurement by hand and drawings of plan or section on graph papers resticted the amount of data that can be captured. Again, according to the *Operational Specifications for Field Archaeology* in China, the depth data and excavated condition of various archaeological sites to be documented is only feasible for paleolithic sites but hardly for neolithic ones, since the relics from neolithic sites are small enough in number to be measured by hand while the abundance of the latter makes it a mission impossible even using total stations.

Plans and sections with insufficient depth data and inadequate description of site layout demands that in the conservation plan and digitized representation, such hand drawn paper output must be converted into digital forms, which is conducive to secondary discrepancy.

Meanwhile, this form of representation casts limitations on archaeological work and research. In the 12.5 meters of depth at *Dahecun*, there are more than 10 cultural strata while currently only the first few layers are excavated. Because of the incomplete information documented in hand drawings, the upper strata must be preserved, so that the lower ones are never to be excavated. Without information of all strata, subsequent research may not proceed. This is the question that most field archaeology has to confront in China.

Suffice to say, whether for the improvement of the accuracy in field archaeology or for future conservation and representation, a convenient, efficient digital-aided archaeology system must be established.

3. System Design

The objective of the system is clear: in the future excavation of *Dahecun* archaeological sites (including areas backfilled and those never excavated), to provide quick and accurate comprehensive documentation of the excavation site, allowing the captured information to be easily converted into visualized data and model for automatical transfer to subsequent research and representation.

For these reasons, two subsystems are designed: digitized tracing and capture subsystem and 4D storage and representation subsystem. The former documents various information from archaeological sites with greatly enhanced efficiency in field archaeology thanks to modern survey technology; the latter stores and visualizes these information.

3.1 Digitized Tracing and Capture Subsystem

This subsystem is divided into two parts of different use, one for on-site real-time documentation, the other for regular survey.

The former is inspired by traditional graph paper drawings. Following CAD modes on tablet computers, archaeologists are

[2] In China, it means "Large Scale Cultural Archaeological Site", later abbreviated to "Large Archaeological Site". The concept already took shape in 1960s, and assumed official recognition in 1995. It refers to archaeological sites of large village, city, palace, grave and tomb of a huge scale, great significance and influence, which reflects the historical and cultural information at various periods.

[3] To reconcile the conflict between Large Archaeological Site and urbanization on the level of city planning in China, the State Administration of Cultural Heritage introduced the concept of "Archaeological Park" in 2010. It contains major archaeological site and its surroundings, and combines the ongoing excavation and conservation with the representation of cultural heritage and recreational park. Serving research, education and amusement purposes, such parks will integrate professional work, transparent management, heritage sharing with daily life of the people.

able to make quick documentations at the site. With interactions of various applications, the vector drawings, simple photos, videos, recordings and panoramas can be integrated. The output is both the origianl data and a complementary for the regular survey.

A regular survey is a comprehensive documentation of the archaeological site with modern survey instruments. It is organized periodically when archaeological work has reached a new stage that demands a whole new update. According to the scale and purpose, a multitude of technical alternatives are available:

a) Total station: for the plans of large- and mid-scale sites, which can be combined with aerial photogrammetry;

b) Aerial Photogrammetry: using unmanned aerial vehicle at different heights to take photos of large- and mid-scale sites, which is capable of producing topographic map with ground calibration from total stations;

c) Close Range Photogrammetry: for measuring mid- and small-scale sites and relics, which can generate 3D models and orthographic projection and sections at any given angle;

d) 3D Laser Scanning: for complex site, remains and relics, which can be applied on large-, mid- and small-scales.

2.4. 4D Storage and Representation Subsystem

This subsystem is essentially an information system based on 3D scenes where "layers" are used to indicate different periods of the site. With the additional dimension of "time", it is named a "4D System".

The whole system is consisted of two parts, storage and representation.

The stored data include unprocessed data, processed data and deep processed data. "Unprocessed data" refers to the raw data captured by the digitized tracing and capture subsystem with various technical measures, such as original photogrammetrical pictures, point cloud from 3D scanning. "Processed data" includes data generated after initial fitting and calculation like the vector plans, aerail photo mosaics, 3D models from direct fitting. "Deep processed data" refers to the data derived from all the above data and archaeological output, such as the manually specified and produced sections, hierarchical diagram of the site, reconstruction proposals of remains and relics. These information is input in an automatic, semi-automatic or manual manner. For now, most of what is stored in the system is object information, and in the future event information (such as excavation, treatment, transfer and mistakes) may be included.

For the representation part, a good effort is made to satisfy all the needs of archaeologist revisit, researcher request and public appreciation. In addition to the display of 3D scenes and coordinate- or object-based data inquery, functions like multi-layer display, opaque display, one-screen comparison are available for comparative research and representation of different periods and types of archaeological sites. It is hoped that this design can promote the establishment and extensive application of the *Dahecun* heritage research and communication platform, enhance the sharing of archaeological work, site information, and research output among the general public, and becomes an integral part of the *Dahecun* archaeological site "virtual museum".

4. Results from Implementation

The system is targeted towards future excavations, but some work has already been done in connection to the existing archaeological document.

Using total station and aerial photogrammetry, the plan and aerial photos have been acquired. The accuracy is good enough for the inventorying of relics on the index map, and can be used as the background of 4D scenes.

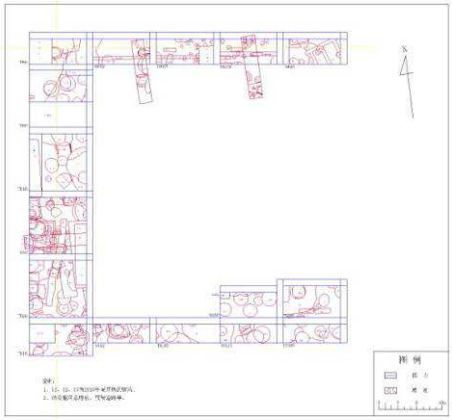

Figure 2. Partial Plan of the Archaeological Site

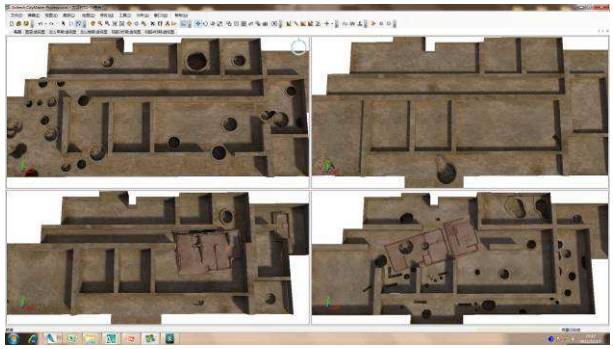

Figure 3. Documentation and Representation of Excavated Strata Using Different Layers in the Reconstructed Model from Archaeological Records

Measurement and modeling of individual trial pits from close range photogrammetry may generate any section, thus proving the possibility of improved accuracy in the documentation of excavation conditions.

With 3D laser scanning, building foundations with complex shapes are documented, and fitted into high-precision 3D models.

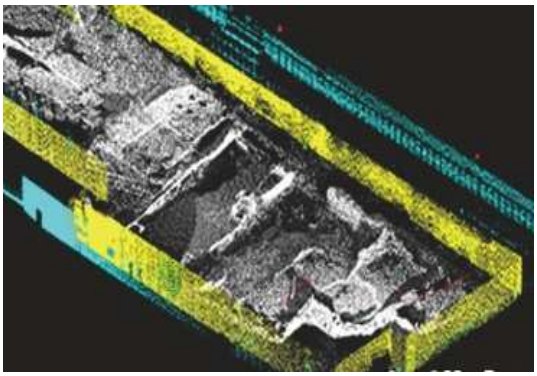

Figure 4. Documentation of the Foundation, Point Cloud from 3D Laser Scanning

Figure 5. Modeling of the Foundation, Generated from the Point Cloud

Combining traditional manual document and latest survey data, a deep processing is implemented to build the 4D scene and data link. Researchers can load up site scenes of different periods and depth on the same screen for comparison. In the virtual museum, visitors can see the archaeological site strata in a realistic way. Archaeologists highly appraise such methodology in that it makes the information more appreciative and the research easier, which is a great progress in the representation of traditional document.

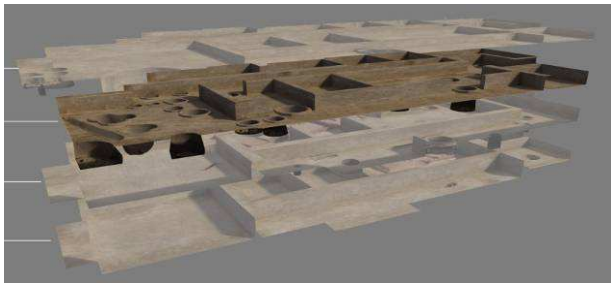

Figure 6. Comparative Display of Multiple Strata

On top of that, from archaelogical and architectural history inferences, the traces of historical treatment shown from the archaeological stie are organized, extended and represented. For example, the construction traces from building foundations are used to reconstruct and represent the building sequence, technique, and roof shape, along with the revision and comparison functions for proposals. It is hoped that this will generate a better communication among scholars to promote progress in archaeological research while disseminate professional knowledge among the general population in a more attractive way so as to serve the purpose of sharing cultural heritage in the society.

Figure 7. Deep Processed Data for the Comparative Research on the Construction Sequence and Technique

5. The Future

The initial aims of the system are to: 1) improve the accuracy and efficiency of the work outside of archaeology in *Dahecun* and 2) promote the visualization of archaeologial information for subsequent research and communications. For the current phase, tablet computer and mobile application based real-time documentation product is being developed, whereas the tracing survey service that assists ongoing archaeological work is yet to be implemented. All other functions have been successfully realized.

In China, there is a booming development of the virtual GIS for field archaeology. The *Dahecun* system is potential of being expanded into a universal one, which can be expected in the future to:

1) Transfer and manage all kinds of data from remote excavation sites using cable or wireless network in a real-time way;

2) Build cable and wireless network based virtual archaeological environment, so that archaeologists in different regions can discuss specific excavation issue and a support provided from experts for remote diagnosis and decision-making;

3) Produce hypothesis for the temporary and spatial distribution of human activities in prehistoric environment based on realisitc 4D scenes and reconstruct its development;

4) Improve the storage and inquiry of "event infomation" to support archaeological operation and conservation treatment.

Finally, it is our sincere hope that this system will promote the advancement of archaeology related work and the integration of archaeology with the conservation of large archaeogical sites and the construction of archaeogical parks, in order that the comprehensive work of the entire cultural heritage career may be brought onto a whole new level.

As is always, we warmly welcome all suggestion and discussions from our colleagues in the world

Acknowledgements

The authors would like to express their gratitude towards *Dahecun* Archaeological Museum for their generosity in providing all the necessary assistance in the virtual reconstruction process.

References

Zhengzhou Municipal Relics and Archaeology Institute (2001): *Zhengzhou Dahecun*, Science Press, Beijing.

China State Administration of Cultural Heritage (2009): *Operationa Specifications for Field Archaeology*, Cultural Relics Publishing House, Beijing.

BI Shuoben, LV Guonian et al. (2011): "Research Framework and Implementation Procedure of Field Archaeology GIS", in China Association of Science and Technology Annual Youth Sympoisum proceeding.

ZHAO Congcang (ed.) (2006): *An Introduction to Scientific Archaeology*, Higher Education Press, Beijing.