

ADVANCED TOPICS IN SCIENCE AND TECHNOLOGY IN CHINA

Dongming Lu  
Yunhe Pan

# Digital Preservation for Heritages

Technologies and Applications



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## 文化遗产的数字化保护: 技术与应用

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## Preface

Cultural heritages include rich information related to social, historical and cultural values. Affected by climate, environmental and other factors, some valuable heritage information is threatened through destruction or disappearance, and some is still not utilized sufficiently. How to investigate and utilize such information effectively is a significant scientific and technological issue. Archaeologists, museologists and conservators are working on issues such as the excavation of precious heritage items, the exhibiting of this valuable information and the strengthening of their outline structure, which aims to conserve and utilize the heritage items as well as their values.

The development of information technology has shown its significant role in large and fast digitalization, personalization and so on. Information technology is more and more important in heritage preservation, including, but not limited to, digitalization, digitally-aided research, conservation, exhibition and utilization. First introduced in the 1980s, information technology was initially used to store information about relics, and then some digitalization and exhibition applications were implemented. Currently, information technology is applied in many different aspects in heritage information preservation. Digitalization can store the heritage information in digital format therefore prolonging the “life” of the heritage items. Digitally-aided research technologies can help to improve the effect and efficiency of the archaeological research. Digitally-aided conservation technologies can simulate the conservation effect and monitor the heritage items in real-time, hence avoiding unpredicted losses. Digital exhibition technologies can remove the time and space limitations of traditional exhibitions, and can also exhibit the implicit values more vividly. Digital utilization can synthetically utilize the historical, cultural and scientific values of cultural heritage items by applying modern science and technology

The digital heritage research group of Zhejiang University has been devoting significant time in this area since 1997, initially taking the Dunhuang Mogao Grottoes as an example and opening up a new area of mural restora-

tion, cave exploration and Dunhuang style pattern design. During the past ten years we have found many new and valuable topics related to heritage preservation, and the research was further extended to heritage information acquisition, digitally-aided research, digital conservation and digital exhibition and utilization. In addition, these technologies are applied to more Chinese heritages, such as the Jinsha Site in Sichuan Province, the Liangzhu Site and the Hemudu Site in Zhejiang Province. The research was financially supported by Key Projects of the National Natural Science Foundation of China (No. 69733030), the National Basis Research Program of China (No. 2002CB312106), the National High-Tech Research and Development Program of China (Nos. 2003AA119020 and No. 2006AA01Z305), the National Research and Development Program of China (No. 2004BA810B04), the Program for New Century Excellent Talents at University (No. NCET-04-0535), the Program for "151 Talents" in Zhejiang Province, and the Program for Changjiang Scholars and Innovative Research Team (No. IRT0652).

Motivated by the systematic introduction of our work as well as recent developments in the area, we aim to provide a comprehensive and up-to-date coverage of digital technologies in cultural heritages preservation, including digitalization, digitally-aided research, conservation, digital exhibition and digital utilization. Processes, technical frameworks, key technologies, as well as typical systems and applications are discussed in the book.

Chapter 1 introduces the significance and the goal of digital heritage preservation. In addition, some technical requirements for heritage preservation are also discussed.

Chapter 2 covers some basic knowledge about digital preservation technologies, including the basis of information acquisition and perception, information analysis and recognition, digital exhibition and interaction. These are fundamental to the following chapters.

Chapter 3 describes the digital acquisition technologies needed for various typical heritage items, including the archaeological excavation field, museum preserved sculptures and artifacts, the large site scene and large paintings and murals.

Chapter 4 discusses some digitally-aided research techniques during the process of archaeological research, among which computer aided investigation of archaeological sites, excavation and computer aided quantitative analysis and research are detailed.

Chapter 5 presents various digitally-aided conservation technologies, including digitally-aided investigation, dynamic environmental monitoring of cultural heritages and digitally-aided restoration of cultural heritages.

Chapter 6 proposes various technologies for digital exhibition and interaction. Distinguished by their objectives, the online heritage exhibition, the reconstructed archaeological sites exhibition and interactive experience in the exhibition hall are introduced.

Chapter 7 brings forward the framework of heritage utilization by taking Dunhuang style pattern re-creation and semantic modeling for ancient Chinese buildings as an example.

Chapter 8 gives some systematic examples based on the technologies introduced in Chapters 3 to 7, including digital preservation for the Mogao Grottoes, digital preservation for the Jinsha Site, digital reconstruction of the Hemudu site and digital exhibition of the Liangzhu relics.

Chapter 9 summarizes the current status and the prospects for future development.

The book is intended for researchers and students in the fields of computer science and technology, museology, and archaeology. We hope it can be a reference book for computer science researchers and students, especially within the areas of virtual reality, computer graphics, computer animation, image processing, and so on. The book can also be used as a reference book for museology and archaeology researchers, who are working on digital heritage preservation applications or projects.

We would like to express our gratitude to Dr. Qingshu Yuan, who has helped with collecting materials for this book. We also deeply appreciate the contribution to this book by our colleagues and the PhD candidates. Our thanks would go to Dr. Changyu Diao for collecting part of the materials for Chapter 1, 2, and 3, Mr. Xifan Shi for collecting part of the materials for Chapter 1, 2, and 4, Mr. Jianming Liu for collecting part of the materials for Chapter 5, 7, 8, and 9, as well as Dr. Yabo Dong and Mr. Ming Xia for collecting part of the materials for Chapter 5. We would like to extend our heartfelt gratitude to Caiping Huang for her helpful work on material checking.

We also owe a special debt of gratitude to Dunhuang Academy, Chengdu Relics Archaeological Institute, Liangzhu Museum, and Hemudu Site Museum, for their cooperative research work.

*Dongming Lu, Yunhe Pan*  
Hangzhou, China  
August, 2009

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## Introduction

Cultural heritages contain rich information regarding society, history and cultural values. How to investigate and utilize such information effectively is a significant scientific and technological issue.

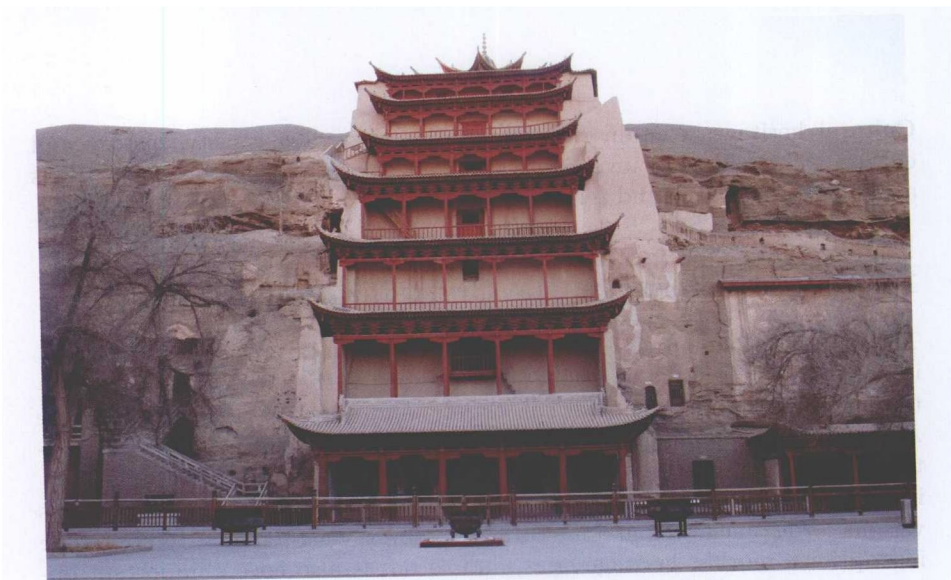
### 1.1 Cultural Heritage, the Crystallization of History

The history of human civilization has left a wealth of precious cultural heritage. Cultural heritage mentioned in this book is the tangible heritage containing various valuable historical, artistic and scientific artifacts. *Heritage Museum-Encyclopedia of China* considers all historical cultural relics, no matter whether they can be moved or not, to be part of cultural heritage (Editorial Department of Encyclopedia of China, 2004). Cultural heritage has various forms, including architectural structures, cave temples, tombs, stone inscriptions, murals, heritage sites, and so on. It also covers important objects, works of art and literature, manuscripts, books, and other articles of interest (UNESCO, 1972). Some famous examples of cultural heritage are listed below to show the historical, artistic and scientific values of heritages.

As the largest and most complete ancient building in China, the Forbidden City, also known as the Palace Museum is the imperial palace of the Ming and Qing Dynasties. the Forbidden City covers over 720,000 m<sup>2</sup> and has more than 9,000 rooms. All architectures were built of wood on a greenish white marble base, roofed with yellow glazed tiles and decorated with magnificent colored drawings, demonstrating the excellent skills of Chinese architecture of more than five hundred years ago. Currently, the Palace Museum preserves a number of precious cultural relics, many of which are unique national treasures. The total number of relics in the Palace Museum is estimated to be about 1/6 of the total in China. the Forbidden City represents a condensed version of the history of Chinese civilization.

The Dunhuang Mogao Grottoes (Yasuo and Dong, 1982) are an artistic treasure and consist of 492 caves containing over 45,000 m<sup>2</sup> of murals, 2,415

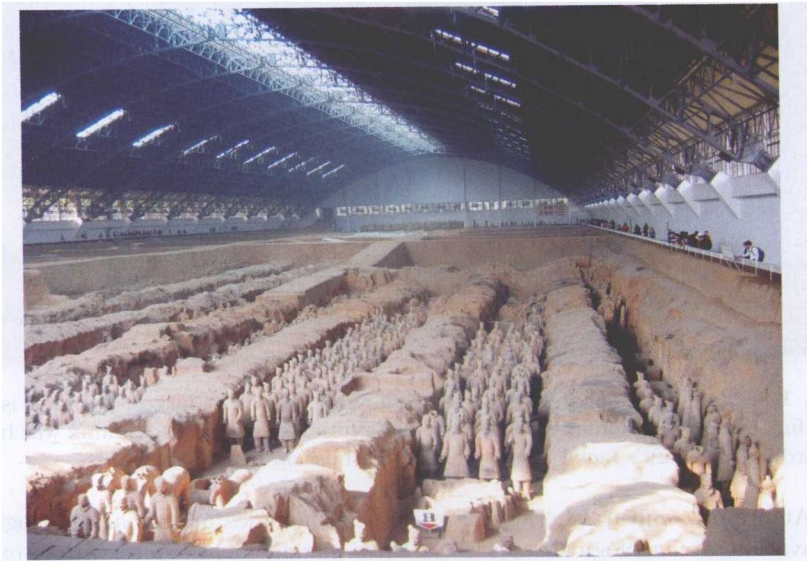
painted sculptures, and more than 4,000 Apsaras statues. In the year 1900, the Library Cave (the 17th cave) was discovered accidentally when the 16th cave was cleared of silt. It contains over 50,000 pieces of cultural relics including writings of previous dynasties, hand paintings on paper and on silk, and embroideries dating from the 4th to the 11th century. the Library Cave is a significant discovery in Chinese archaeological history. This heritage site has important historical and scientific values in the study of Chinese and Central Asian history. The so-called Dunhuangology is mainly concerned with studies of the Library Cave writings and the Dunhuang grotto art. Fig. 1.1 shows the famous architecture of nine floors of the Dunhuang Mogao Grottoes.



**Fig. 1.1.** The architecture of nine floors of the Dunhuang Mogao Grottoes (With permission from Changyu Diao)

In 1974, terracotta warriors and horses (Qin Shihuang Terracotta Warriors and Horses Museum, 1983) were found in the eastern Mausoleum of Qin Shihuang in Lintong, Xi'an, the largest ancient military museum in the world. More than 2,000 pieces of pottery warriors and horses, more than 30 war chariots, over 40,000 bronze weapons of various kinds, as well as many other relics were excavated from three pits. Life-size pottery warriors and horses are arranged in an orderly manner, full of power and grandeur. These warriors represent different regiments of army units, such as chariot soldiers, infantry, and cavalry. The terracotta warriors and horses, as the epitome of the powerful army of the Qin Dynasty, are invaluable for studying the history, politics, militarism, economics, culture, art, and technology of the Qin Dynasty. The terracotta warriors and horses were created in animated

poses. The gestures and facial expressions show the distinct personalities and characters of various people at the time. They represent the peak of the development of ancient Chinese clay sculptures. Fig. 1.2 shows the first and largest pit of the terracotta warriors and horses of Qin Shihuang.



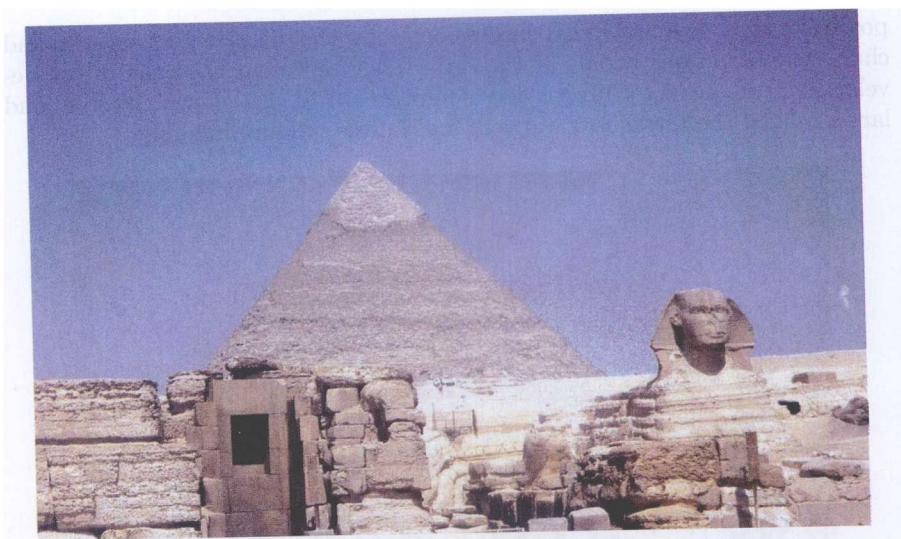
**Fig. 1.2.** The first pit, excavated in 1974, is the largest pit of terracotta warriors and horses of Qin Shihuang. It covers an area of  $230 \times 62$  metres and contains more than 6,000 pieces of terracotta warriors and horses (With permission from Qingshu Yuan)

The Egyptian pyramids (Macaulay, 1982) built 4,500 years ago are called “One of the Seven Wonders of the Ancient World”. From the 3rd to the 13th dynasty, it took ten dynasties to build the pyramids. The pyramids are filled with the ancient Egyptians’ wisdom and they still retain many mysteries. They attract many scientists, archaeologists, historians, and tourists from all over the world. Fig. 1.3 shows the Great Sphinx of Giza.

## 1.2 Cultural Heritage Preservation and Its Objectives

The primary objective of cultural heritage preservation is to protect the authenticity and integrity of cultural heritage (UNESCO, ICCROM, ICOMOS, 1994). Authenticity and integrity are two important concepts conceived in the *Convention Concerning the Protection of the World Cultural and Natural Heritage* (UNESCO, 1972), and also are the basic objectives of cultural heritage preservation. The preservation target is to uncover the implicit value, and find its historical context from cultural heritage itself.





**Fig. 1.3.** The pyramids and the Great Sphinx of Giza. The largest pyramid is for Khufu, the 2nd pharaoh of the 4th ancient Egyptian dynasty. The Sphinx was built according to Khufu's facial features (With permission from Qian Fan)

At present, cultural heritage preservation includes mainly archaeological excavation, archaeological research, archive management, conservation, exhibition, and utilization.

Archaeological excavation includes field excavation, underwater excavation, aerial excavation, and so on. By various means, we can collect unearthed and other artifacts properly, make an archaeological interpretation, and finally complete an archaeological excavation report. Digital technology has expanded archaeological excavation work in various ways. For example, the total station makes measurements of the unearthed cultural relics' positions more efficient and accurate. 3D scanners can easily record the geological surface shape information of the archaeological site.

Archaeological research is dedicated to finding the historical, artistic, and scientific value of cultural heritage, and investigation the historical process, the state of civilization, and the technological level. These goals are achieved through analyzing comprehensively the physical characteristics, pattern characteristics, geographical distribution, and related documentation of cultural heritage items. Digital technology plays an important role in the process of archaeological research; for example, techniques for dating relics based on their shape analysis, and techniques that use 3D visualization to predict the location of heritage sites. All these techniques lend support to archaeological research.

Archive management includes collecting, recording, organizing, adding, deleting and modifying cultural heritage information. Archives of cultural

heritage usually include the number, size, weight, material, unearthed position, unearthed time, dynasty, status, photos, and other information of the relics. With the development of digital technology, digital images, digital videos, 3D models, and other multimedia information have gradually become integral components of cultural heritage archival management.

Conservation work includes monitoring, safely storing, and restoring heritage items. For example, the surrounding environment such as the temperature, humidity, density of carbon dioxide, and the state of microorganisms and vegetation should be monitored in grottoes. The principle of restoration work is to “restore so as to be the same as before”, that is, to maintain the cultural characteristics of the heritage item so as to ensure its authenticity. Digital technology can improve environmental monitoring efficiency. It also helps to strengthen security of heritage information through biological authentication and digital encryption, especially on the net. In the work of restoration, digital technology can help to analyze the physical characteristics of cultural heritage items and restore their original status.

Exhibition work is an important means of cultural diffusion and education, including exhibitions in museums, on site, and even on the Web. Not only is the basic information about the cultural heritage item itself exhibited, but also related historical, cultural and scientific information. Digital technology has brought new forms to exhibitions. For example, virtual reality can make visitors step into the scenes of ancient life through an interactive immersion exhibition, and also give visitors the opportunity to enjoy the images of cultural heritage freely through the network.

Utilization of cultural heritage leads to a better understanding of the culture. Tourism, film, television, game production, imitation, printing, and publication are all utilizations of cultural heritage. With the help of digital technology, it is possible to promote the utilization of cultural heritage values through, for example, pattern creation, animation, and recreation of an ancient cultural style. It is also possible to solve conflicts between the conservation and utilization of cultural heritage, for example, the conflict between conservation and tourism.

### **1.3 New Requirements of Digital Technologies for Heritage Preservation**

Digital preservation technologies have been applied at home and abroad, and have achieved initial success. However, some problems still exist and new requirements are also being raised.

In terms of archaeological excavations, although archaeologists can obtain a lot of information about excavation sites through photographs and drawings, this has not yet achieved the goal of recording all the information. By the time archaeological excavation work is completed, lots of important information produced during excavation might be lost forever.

In terms of archaeological research, there are still many important cultural heritage relics yet to be discovered. Also, secondary damage to relics may occur when archaeologists physically measure and examine them. In addition, many senior experts need to be assembled in one place and time during heritage analysis and identification.

In terms of archive management, the advantages of digital archive management have gradually become apparent. Major heritage units have now turned their attention to digital archive management. However, special equipment is in urgent need to transfer old materials from non-digital to digital forms, such as drawings, films, slides, microfilms, photographs, audio tapes, and video tapes. Such digitalization devices include scanners, digitizers, audio and video capture cards.

In terms of conservation, software can assist experts to mark disease regions and create conservation plans for cultural heritage items. Sensors, wireless network segments, and other equipments can help monitor temperature, humidity, and carbon dioxide concentration of the environment, enabling us to take necessary measures to reduce the environmental impact on cultural heritage items. Virtual restoration experiments have the advantage of being able to be reversed or repeated compared with direct physical restoration. They can also reduce difficulties and risks in the restoration of cultural heritage items.

In terms of exhibitions, visitors can only visit a museum during opening hours, and the content of the exhibition remains the same for all visitors that cannot meet any personalized needs. Also, cultural heritage items suffer a lot from weather or man-made destroy, and original condition of them can not be exhibited. Now augmented reality technology is maturing and becoming applicable to museum exhibitions. In addition, exhibitions need to allow visitors to participate in an interactive experience to get a real feeling for the heritage relic.

Excessive utilization of cultural heritage items has caused severe loss to the cultural heritage. This situation needs to be changed urgently. It is necessary to determine how to maximize development and utilization without damaging cultural heritage. Therefore, digital technology will play an important role in the development and utilization of heritage information because of the non-contact and non-destructive characteristics of its virtual role.

With the emergence of all kinds of new theories and equipments, preservation technologies are also improving with time. In chapters 3 to 7, digital preservation technologies will be introduced in order of their application, as recording, researching, exhibition, conservation, and utilization of cultural heritage relics.

## References

- Editorial Department of Encyclopedia of China (2004) *Heritages & Museum-Encyclopedia of China*. China Encyclopedia Press, Beijing (in Chinese)



- Macaulay D (1982) Pyramid. Houghton Mifflin, Boston
- Qin Shihuang Terracotta Warriors and Horses Museum (1983) Terra-cotta Warriors & Horses at the Tomb of Qin Shihuang. Cultural Relics Press, Beijing (in Chinese)
- UNESCO (1972) UNESCO World Heritage Convention, article 1, 2. <http://whc.unesco.org/en/conventiontext/>. Accessed 10 Sept 2009
- UNESCO, ICCROM, ICOMOS (1994) Nara Document on Authenticity, article 13. [http://www.international.icomos.org/charters/nara\\_e.htm/](http://www.international.icomos.org/charters/nara_e.htm/). Accessed 10 Sept 2009
- Yasuo I, Dong XC (1982) Dunhuang. Shanxi People's Publishing House, Taiyuan (in Chinese)