Mingquan Zhou
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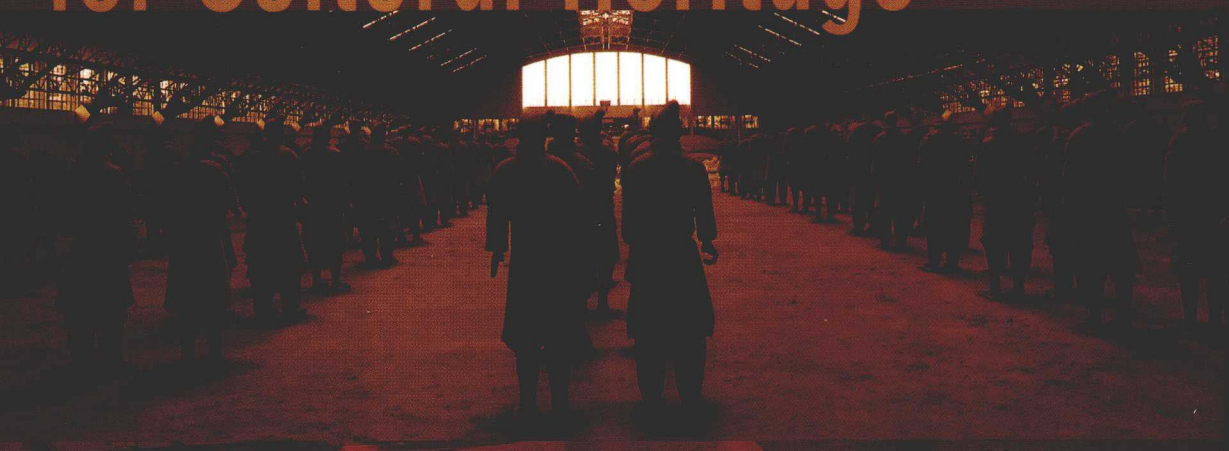
Digital Preservation Technology for Cultural Heritage



文化遗产数字化保护技术（英文版）

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WENHUA YICHAN SHUZIHUA BAOHU JISHU

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Preface

As a great nation with a profound civilization of more than five thousand years, China has a rich resource base cultural heritage. However, due to wars and other negative impacts, much of the cultural heritage has been damaged and corroded. A new era of information richness is coming after the Stone Age, the Bronze Age, the Agricultural age, and the Industrial age. This new era presents us as Chinese researchers and global citizens the responsibility and mission to use information technologies to protect and save cultural heritage for future generations.

We want to be responsible to history. The Chinese cultural heritage is the witness of the history of Chinese civilization and has an impact to over 1 billion people's identity. We want to be responsible for human civilization to make Chinese culture seen no less favorable than any other world civilization, because the Chinese cultural heritage is an important part of the world's cultural heritage. We desire for the future responsibility in the protection and preservation of cultural heritage as a continuation of civilization for all the citizens of the world to explore. We have to be fair to the future generations.

Based on the above basic principles and mission of our work, we have been carrying out the digital protection of cultural heritage for more than fifteen years. With the joint efforts of many computer scientists, archeologists and digital art experts participating in the research field, we have made some important breakthroughs. With the support from the National Natural Science Foundation of China, the State Administration of Cultural Heritage, and the Key Project of the National Research Program of China, this book presents readers a detailed knowledge about the research and practice of digital protection and preservation methods of cultural heritage. It combines information technologies with digitization procedures for cultural heritage, such as data acquisition, model representation and operation, virtual restoration, digital management, web based retrieval, and digital museum exhibition techniques. This book also gives some practical applications in at the end.

With the goal of digital protection of cultural heritage, this book is organized in four parts:

The first part, Chapter 1, summarizes the topics covered in this book. This chapter introduces the basic concepts of digitization protection of cultural heritage, the objectives of protection, conservation status, protection

strategies, protection requirements, and the contents of various research efforts.

The second part, Chapter 2, introduces the fundamental techniques in digital protection of cultural heritage including model representation, geometry processing, model rendering, and computer animation and simulation technologies.

The third part, which includes Chapter 3, Chapter 4, Chapter 5, Chapter 6, and Chapter 7, introduces the special techniques solving the bottleneck issues in the process of digital protection of cultural heritage. Chapter 3 focuses on digitization techniques of the cultural heritage containing overviews of various devices of data capture, 3D reconstruction of artifacts by range-imaging and sequence of images, and 3D reconstruction of cultural sites including terrain modeling. Chapter 4 describes digital management of cultural heritage protection based on digital archaeology and monitoring, which covers digital aided investigation, digital environment archeology and dynamic environment of monitoring systems. At the end of the chapter, an archeological site space information system is introduced. Chapter 5 centers on virtual restoration techniques for ancient artifacts. Fragments classification, digital artifacts representation and fracture-curve-based restoration method are adopted to achieve fragments restoration. This chapter also introduces hole-filling technology to repair incomplete artifacts with an arbitrary shape and estimation methods of symmetric and generatrixes to recover incomplete artifacts with a symmetry-shape. Chapter 6 focuses on virtual restoration techniques for incomplete calligraphy and painting, and demonstrates the use of technology to restore defective areas. Chapter 7 presents the fundamental concepts of digital museum and its major components, such as standards and specifications of the digital collections, display, retrieval, and copyright protection technology of digital collections.

The fourth part, Chapter 8, provides several examples of digital protection of cultural heritage such as the digitalization of the third excavation of Pit One of Terracotta Warriors and Horses of Qin Shihuang and the virtual presentation of Tang Paradise, which is the largest tourist program in Northwest China.

In addition, the book has two features. First, it presents the results of the cross-study of information techniques and artifacts protection, and has a relatively complete scientific interdisciplinary system. With the reference of achievements in domestic and foreign archeological findings, this book constructs the fundamental and application system of Preservation of Cultural Heritage through Digitization, presenting the forefront and progress of the interdisciplinary research. Second, the technologies presented in this book can be adopted with wide coverage and effective application. This book covers the entire process of digital preservation of cultural heritage, including digital capture, collection, representation, processing, restoration, and virtual display. All the technologies in this book are from empirical research and practice of many years in the digital protection of cultural heritage.

I would like to express my great and sincere thanks to the following people for their contributions to this book: Wuyang Shui, Ru Wang, Xuesong Wang, Qingqiong Deng, Xuan Zhu, Xiaodong Zhu, Jun Liu, Jing Zhang, and Yan Hu. I am also grateful to the Key Lab of the Ministry of Education on Cultural Heritage Research and Protection Techniques at Northwest University, Beijing Key Laboratory of Digital Protection, and Virtual Reality for Cultural Heritage in Beijing Normal University, the Palace Museum, Museum of Terracotta Warriors and Horses of Qin Shihuang, Archaeological Research Institute of Shanxi Province for their great support. We, the book authors, are grateful to Mr. Victor Morrison for his great help editing and providing revision of this english edition of the book. Specially thank to Mrs. Chen Hongying from Higher Education Press for her invaluable help.

This book is a good reference not only for researchers and graduates in the majors of computer graphics, image processing, virtual reality, et al. but also for those in archeology, heritage conservation, and museums fields. I hope this book can expand new ways of thought in the digital protection of cultural heritage as well as guidance for the preservation of cultural heritage as well.

Mingquan Zhou
Beijing Normal University
March 2012

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1 Introduction

China is an ancient country with long history and profound civilization, which has numerous cultural remains and archaeological sites. These remains and sites, which are treasures of all people of the world, contain unique spiritual values and ways of thinking, and drive the imagination of the Chinese people and represent vitality and creativity. Protection of the cultural heritage and historical legacies is the key foundation to keep the cultural bonds between people, which is also the prerequisite to maintain the cultural pluralism and the creativeness in the world, and to promote development together. The traditional relocation and replication methods have showed difficulties to reproduce the complete, truthful, and vivid original look of the sites or the culture. The development of informational technology, such as artificial intelligence, virtual reality, multimedia, broadband network, and databases, has provided effective tools for heritage protection. How to apply these technologies to preserve history culture, propel culture protection, and accomplish digital protection, is a challenging problem for archaeologists and computer scientists focused on three-dimension (3D) imaging, and also an important task of contemporary science. contemporary contemporary contemporary

1.1 Review of Cultural Heritage Using Digital Protection

Definition of cultural heritage

The conception of cultural heritage was firstly put forward in the *Convention Concerning the Protection of the World Cultural and Natural Heritage* by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in November 1972 [1]. The convention presented that the cultural property demonstrates the importance, for all the population of the world, of safeguarding this unique and irreplaceable property, to whatever people it belongs. The following shall be considered as cultural heritage: Monuments, Groups of Buildings, Sites, Cultural Landscape, Human Beings Verbal, and Intangible Cultural Heritage.

Categories of the world cultural heritage

Figure 1.1 describes the category of the world cultural heritage. Among them, *material cultural heritage* is of outstanding universal value from the point of view of history, art, or science; *unmovable cultural heritage* is fixed, such as architectural space, natural space, which includes sites of ancient culture, ancient tombs, ancient architectural structures, cave temples, and stone carvings; *movable cultural heritage* includes important authentic objects, art works, historical documents, and manuscripts of different eras. *Intangible cultural Heritage* is represented by diverse traditional cultural expression and cultural aspects, which are closely related to the people's life and could be transmitted from generation to generation, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe, or the knowledge and skills to produce traditional crafts. This book is mainly focused on *material cultural heritage.*

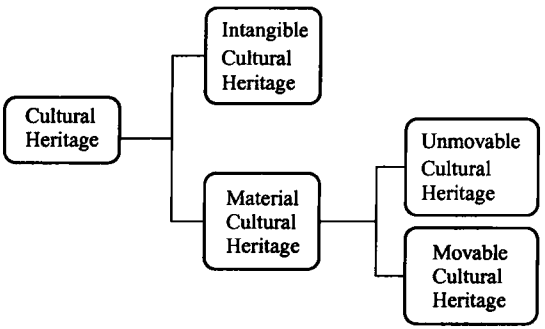

Fig. 1.1 Category of the world culture heritage.

Digitalization of cultural heritage

The digitalization of cultural heritage is the process of digitalizing the movable or unmovable cultural heritage using contemporary remote-sensing and virtual technologies to achieve 2D or 3D digital archiving, for the merits of protection, reparation, restoration, and archaeological research.

Application of digital cultural heritage

The application stratum to provide digitalization of the cultural heritage is summarized in Fig. 1.2.

(1) Digital archiving is a basis for cultural heritage preservation.

(2) Repair and restoration revives the cultural heritage.

(3) Archeological research provides basis for the intrinsic values of the cultural heritage.

(4) Cultural communication and transmission carries forward and develops national culture.

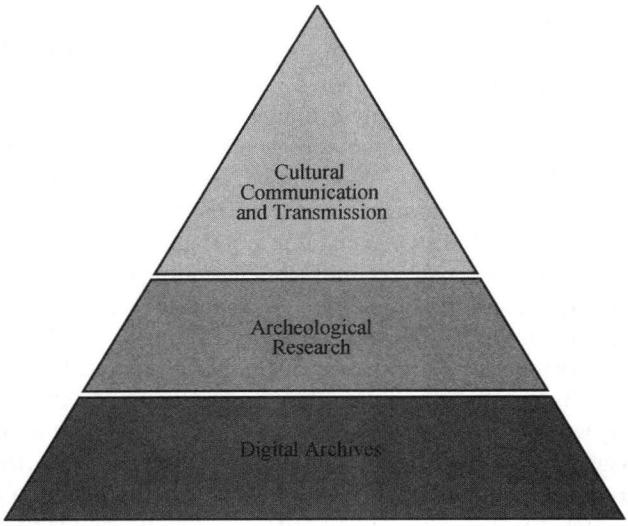

Fig. 1.2 Application stratum of the digital cultural heritage.

1.2 Meaning and Value of Cultural Heritages Digital Protection

Cultural heritage reflects human civilization and wisdom. Protecting cultural heritage is protecting the history and creations of human beings. China is a major world cultural heritage country, which has around 400,000 historic landmarks and sites under conservation. The Chinese government has listed 6,000 sites that are under the protection of state (1,271), province, autonomous region, or municipalities. Six Chinese heritage sites, including the Palace Museum, are approved on the World Heritage List by the Committee for World Heritage in 1987 [2]. Until the end of December 2011, forty-one culture heritages and natural landscapes are inscribed on the World Heritage List [2]. Among them, there are 29 cultural heritages, 8 natural heritages, 4 cultural and natural heritages, and 1 cultural landscape. Moreover, there are 35 additional applications in progress. The civilization's history of over 5,000 years has left us numerous precious heritage artifacts, which are mostly represented with porcelain, jade, and bronze objects. However, for thousands of years, these heritages have suffered unprecedented damage by weathering, war, and historical changes. In modern society with enormous economy development and human activities, a considerable number of heritages have become damaged or broken. Many of them are impossible to be repaired due to some factors, like artificial destruction. For example, many relics of Longmen Grottoes are scattered overseas, which makes the view of a whole Longmen Grottoes impossible. Another example is the Old Summer Palace,

which has fallen into ruin after two disasters. Thus, how to protect these precious heritages using the contemporary science and technologies has become a challenging problem faced by the entire human race.

Information technology not only provides benefits like huge data volumes, high speed computation, multimedia presentation, and on-line access, but also gives an essential and effective approach to protect cultural heritage. It is the obligatory task and historic mission entrusted of computer scientists to restore these destroyed relics by using computer graphics, image processing, virtual reality, and other new technologies, combined with traditional protection and display methods. There is a technical revolution in the cultural heritage protection field by applying digital techniques to it. This will change the traditional techniques and measurements of the cultural heritage protection, and even change the way of thinking and working of the archaeologists.

According to the traditional ways of thinking, heritage should be displayed. However, once the heritage has been separated from their original environment, resulting in the separation from the view as a whole, the damages will be caused to the respective heritages. The museums and other protection organizations could utilize digital technologies and devices, such as multimedia and virtual reality, to rebuild the "Museum Experience", where the audiences could navigate to view the virtual cultural heritages and understand the meaning of cultural heritage as a whole. A comprehensive and complete space of meaning could be rehabilitate and reproduced thus the educational role of digital cultural heritage could be fully exploited.

Related digitalization technologies for cultural heritages are as follows:

(1) High-fidelity, integrated storage and access techniques.

(2) Categorization and digital archives of cultural heritage, and digital techniques to build cultural resource databases.

(3) Virtual museums, virtual reconstruction and rehabilitation of cultural relics, digital simulation and visualization technology of the cultural spaces and procedures.

(4) The technology to recreate the lifestyle, practice, consumption, currency, transmission, and continuity of the traditional craftsmanship.

(5) The pattern and technology to display and transmit the digital cultural heritage.

Currently, the applications of the computer technologies in archaeology are focused on exhibition while deeper and substantive systems in archaeology are rare. Although there are a lot of research and practice bases, the key technologies are still awaiting further research, such as follows:

(1) The modeling, simulation, and rendering technologies of the sites, scenes and heritages to support the original works, such as expert reasoning, forecasting, recognition, proposal, and confirmatory experiments.

(2) The technologies of registering, matching the rigid 3D models, and providing a restoration plan to help the restoration process for archaeologists.

(3) The technologies to exhibit precise antiques and scenes , measurement and transmission of the cultural heritages.

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