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PROCESSING DESCRIPTION WATERMARKING BASED ON LIFE CYCLE FOR CULTURAL RELICS

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Abstract

Data security of 3D model for cultural relics, which has a close correspondence with scientific and technological cooperation and exchange, intellectual property protection, data sharing and many other aspects, has been a research and development focus in the fields of cultural relics, surveying and mapping, archaeology and so on. Originating from information hiding technology, digital watermarking will be a practical and feasible technical mean for protecting security of digital content. After providing an overview of life cycle data of 3D model for cultural relics, the basic principle of 3D digital watermarking and specific characteristics of 3D digital watermarking for cultural relics are discussed. Finally, a watermarking scheme that based on life cycle data of 3D model for cultural relics is proposed in consideration of the application of digital watermarking in the internal data management, internal data distribution and outward data release. It is so beneficial to heritage protection that it will be of higher scientific value.

I. Introduction

As all matters carry both pros and cons, information and networking is also in this way. At the time of enjoying convenience of information and networking, people will have to face negative effects it brings as well. The ability of new technologies to easy store, duplicate, transmit and modify various kinds of digital products (e.g. 2D still image, text, video, audio and 3D model, etc.) makes unauthorized copying, tempering and dissemination of important digital contents a major area of concern [1]. Especially 3D model for cultural relics, which is characterized by high precision, high cost and wide application, draws more and more attention of experts and scholars in related fields. Data security of 3D model for cultural relics will not only have a lot to do with data ownership, but be an issue of major concern to data dissemination and services. And it will become one of the most important factors which restrict extensive sharing and industrial application of 3D model for cultural relics. Especially with the rapid development of networks and multimedia digital technologies, applications of multimedia information on the web become wider and wider, and information security issues have been more and more prominent correspondingly in recent years. As far as the current situation of 3D model application is concerned, the serious security issues existed in data service of 3D model are mainly focused on difficulties of data usage tracking, leakage responsibility tracing and copyright protection.

II. Life Cycle of 3D Model for Cultural Relics

"Cycle" is a term that often occurs in physics and astronomy, as well as in business management. Generally speaking, in the course of continuous movement change, some features may appear repeatedly, and the time it takes to appear two times in a row will be called a "cycle". However, when it applies in a certain area of 3D model for cultural relics, its definition changes a lot. As Horton, a famous American information resource management expert, has put forward that information is live and information resource is also a kind of resources which are with life cycle. Generally speaking, stages of information movement can be divided as follows, namely, information generation stage, information protection stage, information application stage, information archiving stage and information processing stage. Therefore, as one type of information, 3D data for cultural relics has its own life cycle as well, what refers to the whole time from the birth of data production requirement through data acquisition, data dissemination, data processing, data storage, data utilization and even data destruction when necessary. What is shown in Figure 1 is a simple description of data processing of 3D model for cultural relics. According to the procedures of data acquisition and processing, 3D data for cultural relics consist of point cloud data acquired by 3D laser scanning, texture data collected by high resolution camera, model data after data processing, real 3D model data after texture mapping, digital orthophoto map, digital line graphics, sectional drawing and so on. Additionally, in the course of data processing, 3D model for cultural relics is generated accompanied by its metadata, such as data format, data content, data

storage location, historical operations, file records, etc. These data are mainly used for storage, exchange and management of data and are collectively called life cycle data of 3D model for cultural relics (as demonstrated in Figure 2).

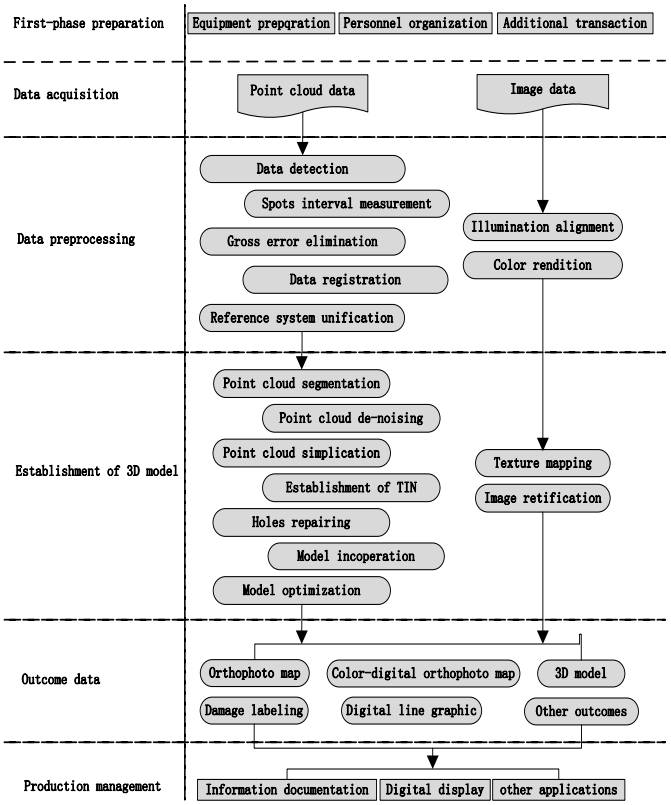

Figure 1. Data Processing Flow of 3D Model for Cultural Relics

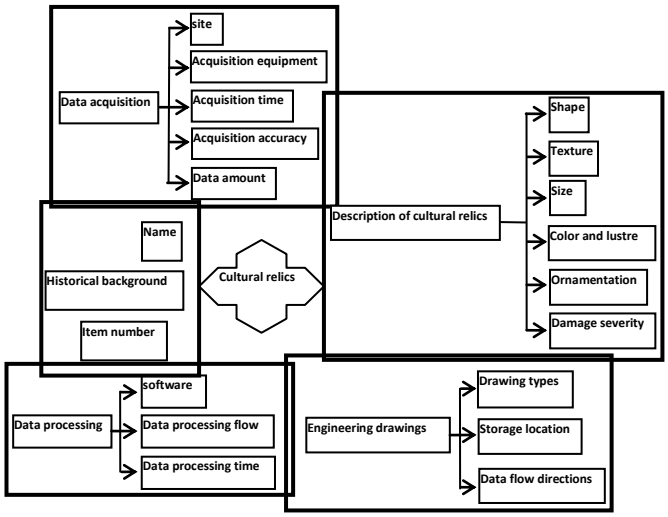

Figure 2. Life Cycle Data in 3D Recording and Documentation for Cultural Relics

III. 3D Digital Watermarking for Cultural Relics

Digital watermarking technology, as an important branch of data hiding technology, is a cutting edge technology in the field of multimedia information security, among which, research on the key techniques of 3D digital watermarking for cultural relics has received extensive attention from academia and industry departments, especially with the comprehension strengthening of historical monuments conservation. 3D digital watermarking for cultural relics, which achieves a certain function through adding some specific watermark information into 3D model for cultural relics, is mainly used for information labeling, authenticity and reliability verifying, ownership establishing, data dissemination monitoring, and even data leakage source tracking, when necessary, as a basis for identification, prosecution of illegal infringement. Additionally, embedded watermark can not only be some ownership information of the copyright holder, but some description information associated with carrier data, and even some information meaningless. And whether one kind of watermark can be the most suitable one to be embedded is often contingent on the specific application.

A. Basic Framework of 3D Digital Watermarking

A whole 3D digital watermarking system is mainly composed of three parts: watermark generation part, watermark embedding part and watermark detection and extraction part. In order to further enhance intensity of the whole watermarking system, and increase difficulty coefficient of attacks on the system, two different keys are often applied in a watermarking system, i.e., generation key and embedding key. Additionally, classification method of 3D digital watermarking is varied. And according to different criteria, there will be different categories. This paper performs an in-depth research on 3D digital watermarking in different application fields, and the basic principle and applications of 3D digital watermarking is shown in Figure 3.

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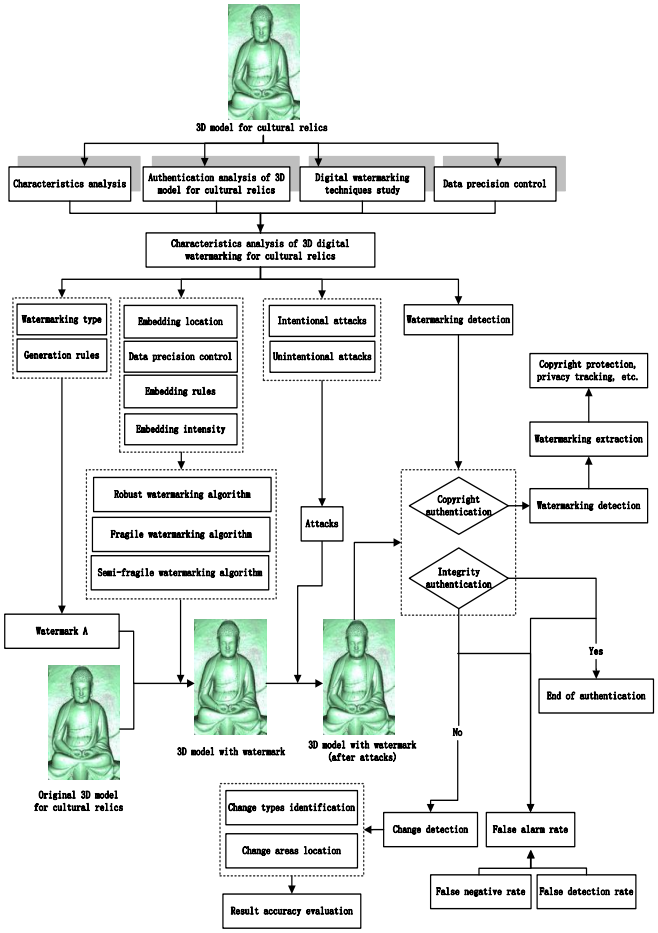

Figure 3. Basic principle and applications of 3D digital watermarking

B. Specific Requirements of 3D Digital Watermarking for Cultural Relics

In general, 3D digital watermarking should meet the following several requirements [2-3], such as robustness, imperceptibility, uniqueness, data capacity and so on. However, compared to 3D model for conventional entities, 3D model for cultural relics is characterized by its own characteristics. Firstly, China is a country with a long history of ancient civilization and the cultural relics are also beyond count. Especially large stone statues, inscriptions on precipices, murals are not only exquisitely designed, but magnificently layout, which determines data quantity for cultural relics will be generally massive and the process of analyzing data will be correspondingly more complex. Secondly, 3D model is elementary data for cultural relics, which is with high accuracy. All kinds of information are clearly visible that it can provide fundamental data for digital storage, damage detection and labeling, virtual restoration, 3D display, archaeology, scientific research and so many other applications. It is the notable characteristics of 3D model for cultural relics (e.g. large quantity of data, high accuracy requirement, complicated hierarchy, etc.) dictate that apart from the conventional 3D watermarking requirements, additional characteristics requirements in the following are needed to meet as well.

(1) Accuracy

Original point cloud data, which is the most authentic 3D data for cultural relics, have been widely used in the heritage protection [4]. Firstly, it is the most accurate and essential data for cultural relics, which can not only realize precise 3D measurement of specific areas, but address problem of high precision digital recording and documentation. Secondly, when the cultural relics are subjected to irreversible damage, it can offer the most powerfully theoretical and experimental support for damage detection, damage labeling, damage statistics and subsequent virtual restoration (as shown in Figure 4) [5]. Thirdly, through the processing and comparison of 3D point cloud data collected at different times, it can also provide a quick and accurate way to monitor and analysis of the current status of virtual restoration (as shown in Figure 5) [6]. Furthermore, cultural relics in China are always not only exquisitely designed, but magnificently placed, thereby high precision will be a fundamental feature of 3D data for cultural relics. The 3D data for the next step of heritage conservation should not only meet the requirements for conventional 3D digital watermarking (e.g. embedding efficiency, uniqueness), but ensure its accuracy in the absolutely allowable range, and will have no effect on the subsequent application, such as damage detection, virtual restoration, deformation monitoring and so on.

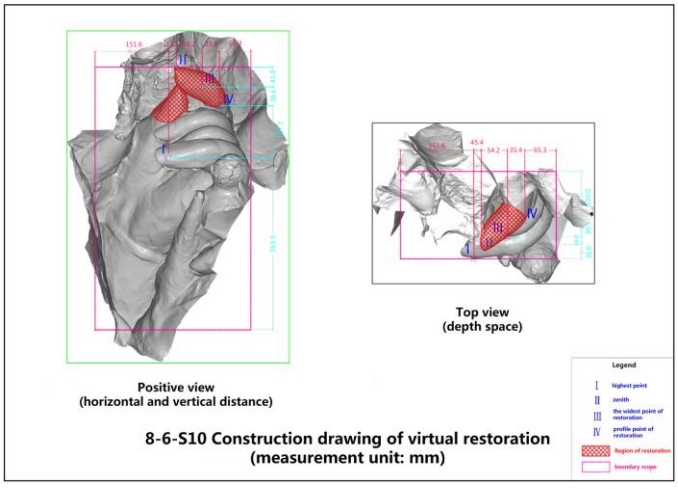

Figure 4. 8-6-S10 Construction drawing of virtual restoration for Dazu Thousand-Hand Bodhisattva Statue in China

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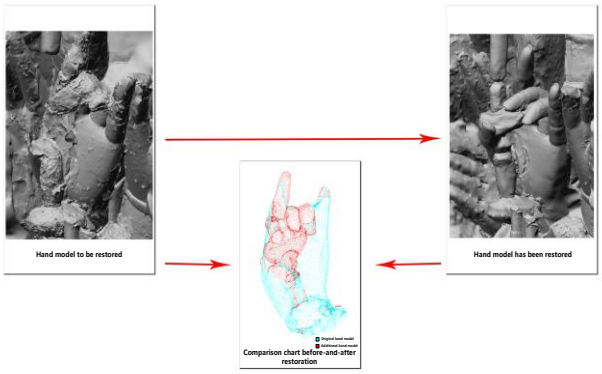

Figure 5. 8-6-S10 Comparison chart before-and-after restoration for Dazu Thousand-Hand Bodhisattva Statue in China

(2) High Efficiency

Data amount of 3D model for cultural relics is always exceedingly huge, which brings great difficulties to data application. Taking DaZu Thousand-Hand Bodhisattva Statue in China for an example (as shown in Figure 6), Dafo sinus of Baoding Mountain is a reasonable community of integrated overall arrangement and rigorous conceptual design. And its Thousand-Hand Bodhisattva Statue in the 8th shrine is also the largest 3D carved stone statue in China, about 7 meters high, 10.9 meters wide, approximately 84 square meters of projected area and 210 square meters in size [7]. Fine 3D scanning on the whole statue was conducted with high precision scanner (Romer) before and after restoration, the total data were 301G (before restoration) and 151.2G (after restoration). And in the process of in-situ restoration on the spot, some data were supplemented with a data volume of 18.6G. Hence one can see that data amount of 3D model for cultural relics will be profoundly large. Therefore, compared with conventional 3D model, 3D digital watermarking algorithm for cultural relics should be more efficient and practical.

However, each technical requirement of 3D digital watermarking, in general, is mutually influenced by each other and even presents a contradictory relationship. And the relative importance of each technical requirement always depends on the role of watermark. For example, the smaller data capacity is, the worse robustness will be, and the larger data capacity is, the weaker fidelity will be. All in all, in practical application, designing digital watermarking algorithm based on specific data characteristics of 3D model for cultural relics and choosing the best compromise among conventional requirements, accuracy and efficiency will be essential and inevitable.

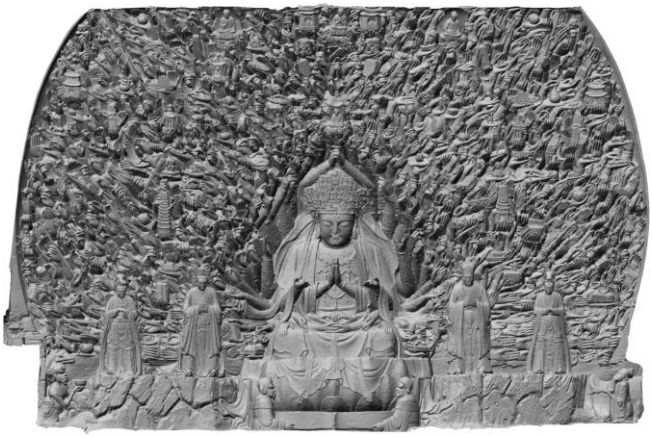

Figure 6. Sub millimeter model for Dazu Thousand-Hand Bodhisattva Statue in China (before restoration)

IV. Application of Process Description Watermarking based on Life Cycle in Heritage Conservation

Process description watermarking based on life cycle, which mainly refers to taking life cycle data of 3D model as watermark and embedding it into 3D model to be an inalienable part of the carrier data, is of great significance in heritage conservation.

A. Ownership Protection

Utilizing digital watermarking technology to protect ownership of digital products is one of the most important applications of digital watermarking technology [8]. In this application, taking life cycle data (e.g. copyright mark or license information that can uniquely identify ownership of the carrier data) as embedding watermark and adding it into 3D model for cultural relics. In case of a copyright dispute, the copyright identification can be extracted accurately and uniquely to achieve purpose of protecting rights and interests of multiple copyright holders. What needs note that the watermarking algorithms for application in this field must have better robustness, security and uniqueness.

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B. Content Protection

According to visual effect, digital watermarking algorithms can be divided into visible digital watermarking algorithm and invisible digital watermarking algorithm. In terms of current research situation, most of related study has been focused on invisible digital watermarking algorithm and a considerable progress has been made in the area of 3D polygonal meshes watermarking [9]. Sometimes, however, in order to rev up knowledge propaganda and improve quality of industrial services, for one thing, data owners may encourage subscribers to scroll through the data in a more open and free circumstance, but for another, they may also argue against illegal commercial abuse. Thereby, embedding visible digital watermark, which is difficult to remove, can be an effective and excellent choice. Visible digital watermarking, whose main goal is to flag data information and display a copyright notice, can be perceived by human intuition. Although the commercial value of data can be reduced to a certain extent, it may have little impact on conventional use of subscribers. And it does meet the requirements of content protection.

C. Privacy Tracking

Data distribution, which is an inevitable process of data industrialization, will be the weakest link in data security. As things stand, forms of data distribution are mainly depending upon hard disk copy. In other words, data recipients go and get the hard disk, on which related data has been stored in advance, after the implementation of relevant procedures for data collection. However, all the hard disk copy data received here are not identified by themselves. Thereby, once data security problems, such as illegal data spread and exposure, occur, it is bound to be difficult to trace the source of data leakage, not to speak of the responsible person. Digital watermarking based on life cycle data can be a safe and effective approach to data flows monitoring and leakage source tracing. Therefore, in the event that subscribers of the data to be outward release are far more than one, it may be possible to embed life cycle data information of 3D model for cultural relics that are each distinct into every 3D model data which are ready to be outward released to distinguish and identify different subscribers, in case of the situation that data is being used without authorization. In this way, once the copyright holder find any case that the 3D model data is being used without authorization, he can track the data exposure source through extracting and detecting the unique watermarking information from the 3D model that non-authorized subscriber used, thus achieving the purpose of illegal data source inspection and privacy data tracking.

D. Data Internal Management

(1) Caption and Remark

Data processing of 3D model for cultural relics is a delicate and complicated process. Moreover, in the practical process of data production, the whole data processing is often not dealt with by certain of person in a certain department. Therefore, it will be an indispensable work to strengthen the cooperation between departments and personnel in the whole process of data production to update the abreast of advances in data processing more timely and avoid confusion and duplication of data as well.

Additionally, for multi sources in project of 3D information recording and documentation, current commercial point cloud data processing software are mostly based on file data management, such as Geomagic studio, Trimble tealworks, Cyclone, Terrosolid and so on. However, data processing in this mode cannot guarantee validity, correctness and compatibility of data, as loss of corresponding life cycle data and there is no favorable description information on the data authenticity, resulting in data reliability reduction. Regarding title or some brief explanatory note that directly perceived through the senses as watermark and embedding it into 3D model for cultural relics can be a further description of the carrier data, which can not only avoid issues of repetition or lack of authority due to data confusion, but further strengthen internal management during data production. When it comes to the practical production, the concrete watermarking information can be life cycle data of 3D model for cultural relics, such as data source, data acquisition time, data collectors, historical operation, final revision time, data distribution, subscriber's unique identification information and so on.

(2) Data Hiding

The reason why some information needs to be hidden may lie in its characteristic that it does not need to be displayed directly or the information itself is more confidential than the carrier data. For example, some important life cycle data (e.g. reflection intensity of scanning spot, original point cloud precision, point cloud interval, header files,

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parameters for data acquisition or processing) will directly affect the precision and quality of data acquisition and fine modeling of 3D model for cultural relics. Therefore, it will be of great economic and practical application value to implement safety protection of important life cycle data, and watermarking for flag hiding is just to offer a new method to solve this problem, which is more scientific, convenient and reasonable. Additionally, with the idea and technology of digital watermarking, important life cycle data can be embedded into the 3D model and being an inalienable part of the carrier data. On one hand, it can cut down data storage space so as to lessen communication rooms, on the other hand, it can also ensure the proper use of carrier data even in the case of life cycle data loss due to device missing or theft, which will be of great significance to the widespread application of multimedia data.

V. Conclusion

3D cloud data, which is the most authentic and accurate data for cultural relics, has been more and more deeply utilized in the fields of digital recording and documentation, damage detection and labeling, virtual restoration, deformation monitoring, 3D display, 3D mechanical analysis and other aspects. At the same time, the security problem faced by the 3D model for cultural relics is getting more and more serious as well. Thereby, it is urgent to integrate reliable technical means to protect data security. Digital watermarking technology, as a frontier technology of digital data security, plays an important role in the data security protection of 3D model. On the basis of research and application of digital watermarking of 3D model for cultural relics, a new watermarking scheme that based on life cycle for cultural relics is proposed by analyzing the actual data characteristics and application needs of cultural relics, which will be of great significance in the data security protection of 3D model for cultural relics. However, different from the watermarking algorithm used for illegal data stream source tracking, in the process of data production, process description watermarking based on life cycle for cultural relics needs to carry on the data of the same model for multiple watermarking embedding and extraction, which is easy to produce error accumulation problem. Thereby, properly dealing with error accumulation will be a difficult problem in the study of process description watermarking based on life cycle for cultural relics.

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