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Research of Metadata Construction Approach on 3D Model Database

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Abstract—It's important to construct 3D model database to prevent repeated resource construction and information island, and the unified metadata standard is the basis and essential prerequisite of model database construction. Firstly, the model metadata framework which is represented by 2D matrix is designed through comparing the home and abroad metadata standards in this paper. Secondly, the 3D model's metadata will be constructed through the combination of manual metadata marking and automatic metadata extraction. Finally, a shared service system is developed to verify that this approach can fully demonstrate the characteristics of 3D model and improve the retrieval efficiency.

Keywords-3D model; Metadata Standard; Model properties; Geometric features; Semantic relation

1. Introduction

The research of 3D model database is still in development stage. Because of the lack of unified storage specification and technical standards, it's difficult to achieve resource sharing and information exchange. As a result, many problems emerged, for example, the duplication construction of resources, high development cost and low resource utilization ratio. Therefore, it's urgent to design a unified metadata standard to realize the standardization and scientization of model management [1]. Metadata is commonly defined as data about data [2]. Metadata can help organizing 3D model resources, providing digital identification, and supporting archiving and preservation [3]. Broadly speaking, metadata not only describes the resources, but also organizes and manages the resources. In order to describe the model resources clearly and accurately, the metadata standard should be designed through referencing model characteristics to increase the retrieval efficiency. Therefore, the metadata structure of 3D models should have a three-layer architecture after comparing domestic and international metadata standards and model attributes, and also the metadata content should contain model attribute information, geometry feature information and semantic information, so that it can support keywords retrieval, semantic retrieval and content retrieval. Therefore, the framework of model metadata will be divided into 2 dimensions: metadata structure and metadata content, and each dimension has three elements.. Then the framework can be represented by 3*3 matrix. In the metadata construction stage, the model attribute and the semantic relation information will be inputted manually, and the geometric feature information will be extracted automatically.

This paper is organized as follows: In section 2, an approach for designing the metadata framework of 3D model is introduced. Section 3 describes the construction of metadata. Finally, section 4 verifies the feasibility of this construction approach through the culture resources sharing and service system which is developed by project team.

2. Metadata framework of 3D model

2.1 Metadata Standards at Home and Abroad

3D model belongs to the field of Multimedia. In recent years, some organizations issued many metadata standards about different types of multimedia resources. The design of 3D model metadata can reference this related standards, such as MPEG-7 standard [4], ISO 15846 Dublin Core metadata standard [5], multimedia metadata standards of Peking University [6], Multimedia metadata standard of scientific database [7] and so on. This section will introduce three standards which are used in many areas:

1) *MPEG-7 Standard [8]:* MPEG-7 is a multimedia content description standard. This description is associated with the content itself, to allow fast and efficient searching for material that is interesting to the user.

2) *Dublin Core [9]:* The Dublin Core set of metadata elements provides a small and fundamental group of text elements through which most resources can be described and cataloged. Using only 15 base text fields, a Dublin Core metadata record can describe digital materials such as video, sound, image, or text files. Metadata records based on Dublin Core are intended to be used for cross-domain information resource description and have become standard in many fields.

3) *Multimedia metadata of Peking University [10]:* This multimedia metadata standard fully considers the characteristics of multimedia resources, and embodies the principles of integrated design. This standard has a strong compatibility, so it could solve the problems of media diversity and relationship complexity.

2.2 The Design of Metadata Framework

The standard which is designed should in the utmost exchange and be compatible with the existing metadata standards when we construct the metadata standard of 3D model. However, the current metadata standard is too concise in content description [11]. In addition, 3D model has its specific features, such as complex type, rich content and multiplicity formats and so on. A model can be divided in precision model and simple model according to precision grade. It also can be divided into scenes, props, characters and other kinds of resources according to model content and it has many formats too, such as *.max, *.3ds, *.obj, *.mb and so on. Furthermore, 3D model is not only complex, but highly semantic. As a result, the characteristics are difficult to describe precisely and the resource information is difficult to express. Thereby, this section will analyze the metadata framework from two dimensions: metadata structure and content, so that it can describe the information of 3D model all-sidedly.

Metadata structure: 3D model has various types and different model content has different attributes. Take the Chinese classical architecture model for example, the metadata of this model should have some exclusive attributes, such as architectural style, age, area and so on. As a result, in order to achieve the management of 3D model effectively, this standard takes some necessary expansion of DC metadata, and uses three-layer metadata structure which is shown in Fig.1.

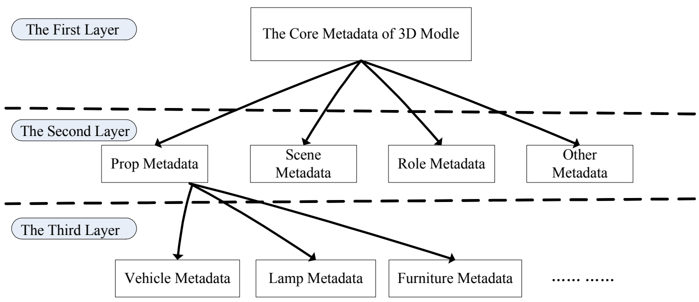

Figure 1. Three-layer metadata structure of 3D model

The first layer is the core metadata of 3D model. This layer realizes the unified management through extracting the common attributes [12]. This layer of core metadata elements references the Dublin core metadata. The elements contain model name, model type, model author, precision grade, production time, upload time, upload worker, producers software, keywords, summary or description, copyright information, unified identity, and related resources.

The second layer metadata includes the metadata of prop, scene and role. The purpose of this layer is to reflect the specific attributes of different model content, for example, “gender” is a essential property to describe the role model, but other model do not need this attribute, so it’s the special attribute for role model metadata.

The third layer is the specific metadata which is based on different category. The metadata of this layer should be designed under the participation of various research organizations. Take prop metadata for example, vehicles, lamps, furniture are all props, and they also have their specific metadata and semantic relations. Consequently, this part of metadata standard needs the participation of experts who is worked in different fields.

4) Metadata content: From the perspective of resources retrieval, the content of metadata includes model attribute information, geometry feature information and semantic information, so that it can fully demonstrate the complex content of 3D model. Model attribute information is to describe the common and specific attribute information. Geometry feather information is to describe the geometric attribute, appearance attribute and other geometry information. Semantic information is to describe the semantic relationship between models and model components. This part will take architecture model as an example.

a) Model attribute information: As a multimedia resource, this information describes the model's common attribute and architecture model's specific attribute, such as architecture type, architecture structure, architecture style, age, region, architecture materials and nationality etc.

b) Geometry feather information: This information describes the geometric attribute, appearance attribute and other geometry information. Geometric attribute describes the spatial relationship of point, line and surface, as well as the specific shape features and topology which is composed. Appearance attributes include materials, texture, mapping design and so on. The content of geometry feather information is shown in Fig.2.

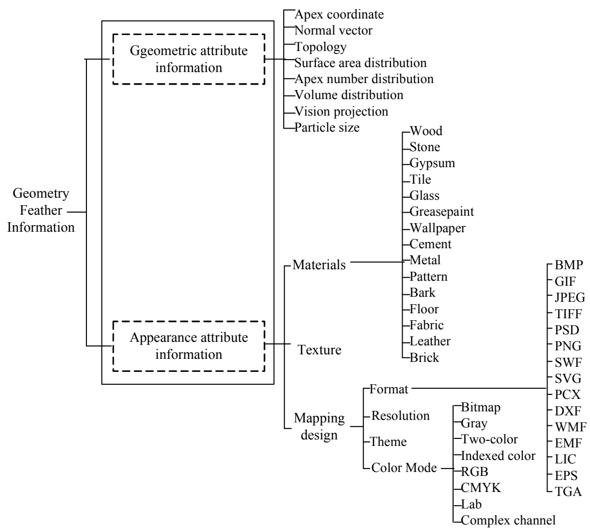

Figure 2. The geometry feather information

c) Semantic information: This information describes the semantic relationship between architecture model and internal components, specifically including component semantic information, object semantic information, scene semantic information and relation semantic information.

5) Metadata 2D matrix: From the above metadata structure, 3D model can be divided into three layers, while the metadata content can be divided into three parts: attributes, geometric and semantic information. Therefore, the framework of model metadata will be divided into two dimensions: metadata structures and metadata content, and each dimension has three elements. Then the framework can be represented by an A33 matrix which is show as follows.

$$\begin{bmatrix} a_{11}, a_{12}, a_{13} \\ a_{21}, a_{22}, a_{23} \\ a_{31}, a_{32}, a_{33} \end{bmatrix}$$

In this matrix, transverse dimension represents the granularity of model metadata structure which has 3 layers; vertical dimension represents the granularity of model metadata content which is also divided into 3 main parts. The elements a_{ij} represents a certain layer model's metadata collection which is composed by certain content. For example, a_{11}=(the core attribute information of 3D model), a_{12}=(the core geometry feather information of 3D model), a_{13}=(the core semantic information of 3D model); a_{21}=(the special attribute information of props, the special attribute information of scenes, the special attribute information of roles)， a_{22} and a_{23} which are similarly to a_{21}, are used to represent the geometry feather and semantic information of props, scenes and roles; a_{31} = ((the special attribute information of weapon, the special attribute information of transport, ...), (the special attribute information of indoor scenes, the special attribute information of outdoor scenes, ...), (the special attribute information of people, the special attribute information of animals, ...)), a_{32} and a_{33} which are similarly to a_{31}. This 2D framework can fully demonstrate the characteristics of 3D model and can be used for other multimedia metadata.

3. The Construction of Metadata

In constructing the model metadata, it's important to develop some metadata operation tools according to corresponding model metadata standard, including software that can input, edit and retrieve in various operation environment [13]. Therefore, a perfect platform of metadata construction which is shown in Fig.3 should contain metadata extraction and import tool and the underlying database. The underlying database stores up metadata information and model files. Metadata extraction and import tool will import the model metadata to database [14]. In this step, model attribute information and semantic relation information will be inputted manually. The geometrical characteristics information will be gained by automatic extraction tools. So, metadata processing is the core of the platform, and what's more the extraction and import of metadata is regarded as the foundation of the platform. This section will discuss manually making and automatic extraction respectively.

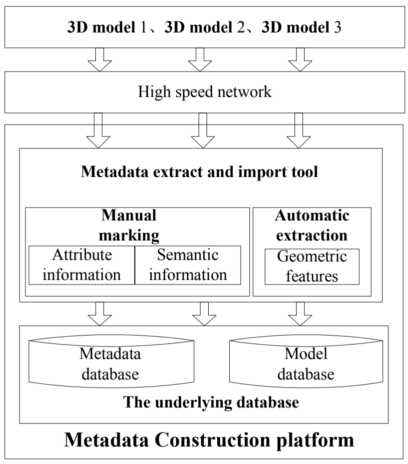

Figure 3. Construction platform of metadada

3.1 Manual Marking

In order to mark the content and semantic information of 3D model clearly, the resource description template which is shown in Fig.4 is designed based on the analysis of model metadata. Take architecture models for example, we can mark the model's attribute information, model component semantic information, object semantic information, scene semantic information, relationship semantic information manually so as to describe the resources completely.

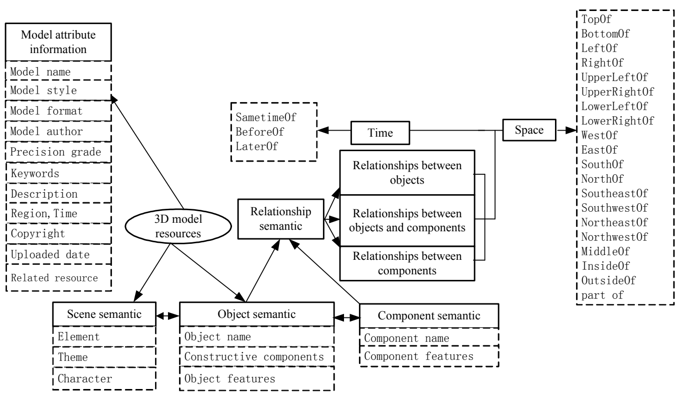

Figure 4. The description template of 3D model resources

6) The description of model attribute information: This information describes the architecture model's common attribute and specific attribute. Fig.5 is the description interface of model common attribute.

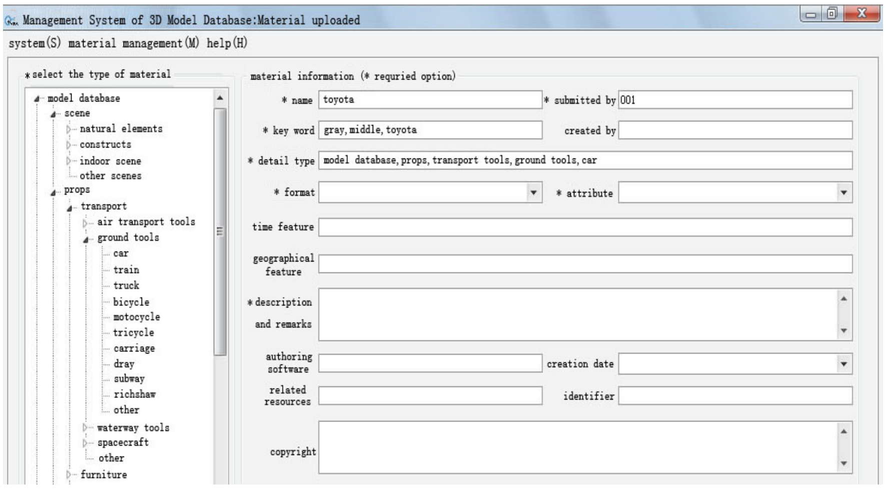

Figure 5. The interface of model common attribute upload

7) The discription of scene semantic information: The scene semantic information is the scene content which is presented by model, including the background, scene theme and objects in the scene [15].

8) The discription of object Semantic information: This information is to describe the single objects in 3D scene, such as the object name, type, features, components and other aspects. Take the three main hall model of the Forbidden City for example, we can describe Forbidden City which composed of three main halls on all 3D scene objects (Hall of Supreme Harmony, Hall of Central Harmony, and Hall of Preserving Harmony) respectively to describe the characteristics of Hall of Supreme Harmony clearly and accurately.

9) The discription of component semantic information: The component which can form a full model is a collection of 3D lattice, such as doors, windows, walls, roof and so on in architecture model. These components can constitute various 3D models through different combination. Therefore, this information is to describe the relationship of components in the object. Fig.6 describes the object and component semantic information of the 3D model of the Hall of Supreme Harmony.

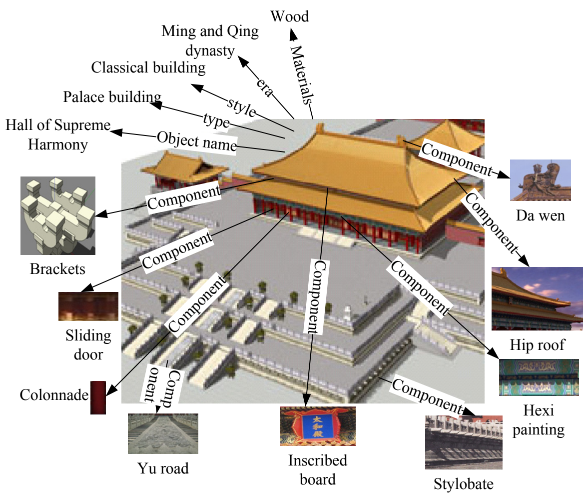

Figure 6. The semantic information of Forbidden City

10) The description of relationship semantic information: This information is to describe the time and space relationship that between objects and components which exist in three dimensional scenes.

3.2 Automatic Extraction of Geometrical Features

When entering metadata we need to automatically calculate and extract the feature data of 3D model (such as shape, spatial relationships, material color and texture, etc.) Since the content-based retrieval need to compare the shape of the main properties and appearance characteristics, therefore, the geometric features auto-extraction tool only need to extract geometric attributes (vertex coordinates, the shape of the distribution of spindle orientation, etc.) and appearance attributes (vertex color, texture, map, etc.) .This tool is developed by Maya API, it can automatically extract the geometric properties and appearance properties of 3D model. For example, it can extract center coordinates, length, width information from the 3D Warehouse model format *. mb and output it in XML-format ,as shown in Fig.7.


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```


Figure 7. Extracting the geometric features

4. System Verification

4.1 System Function

3D model database is an important part of cultural resource sharing and service system. Depending on 3D model database and audio database, video database and other database which is constructed by the same approach, our project team has developed a web-based distributed sharing and service system so as to make the rich resources can display instantaneously and dynamically according to the special request of various users. Fig.8 shows the essential modules of the system.

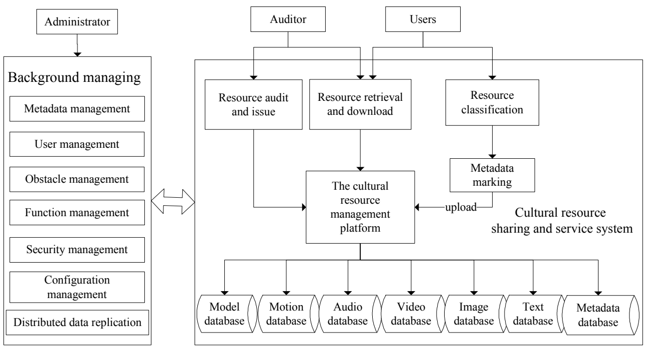

Figure 8. System modules

This system is made up of two major modules: resource management module (resource classification, metadata marking, resource audit and issue, resource retrieval, etc.) and background managing module (metadata management, system configuration management, etc.). Users can be classified into administrator, auditors, users and other roles according to different authority. Since the system is based on B/S structure, the client can use it simply by a browser.

4.2 Application Analysis

This system which has been built by the metadata construction approach has been used by some enterprises in Wuhan city and Guangdong province. Most users mainly work in the field of animation and games. After a period of testing, the system is proved as stable and in good condition. The feedback of users mainly focuses on the following two points:

- The construction approach of metadata is conducive to the sharing of resources, reducing duplication of resources, saving storage space, and improving resource development effectively [16]. Fig.9 is the retrieval result page of model.
- Resource rights are assigned to different users through the rights management system. Tasks are decomposed and the individual user is responsible for their own collection of the professional field resources. With the help of this approach, the efficiency of resources collecting is improved greatly and unnecessary waste of resources is reduced either.

Figure 9. Retrieval result page

5. Conclusions

This paper introduces the construction approach of 3D model metadata, and validates the approach with a cultural resource sharing and service system. Through the test of the system, it shows that this approach can help users to retrieve the useful resources by various ways, and the result shows that it is feasible and effective.

6. Acknowledgment

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