

3D Database System of Mercede Church : The Use of 3D Models as an Interface to Information

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Abstract. Advancement in 3D modelling technologies has enabled us to obtain high resolution 3D models of real objects, for example historic buildings. Unfortunately, however, the application tools for large models have not been existed, which allow experts and other people outsidess of the field of computer engineering to utilize the 3D models effectively. We introduce a GUI-based application tool enabling users to easily add and manipulate optional information on the certain area of 3D models, and to retrieve that information when viewing the 3D models. The “3D database system” can deal with much information by connecting to existing database systems. In addition to that, we realize efficient selecting surfaces and accessing information on the regions for large models, using a segmentation method of 3D models’ surfaces. We demonstrated this tool using the 3D model of Mercede Church, in Panama City.

1. Introduction

Recently, the improvement of 3D modelling technologies has enabled us to obtain large 3D models in fine detail. The accurate 3D models are very useful, not only for digital storage of real objects, but also for the production of multimedia contents that allow us to view the objects from various viewpoints. This technology has contributed to the activity of preserving and displaying objects of precious historical heritage [1, 2, 3].

However, the range of restoration activities of cultural objects is limited by only using 3D graphics images of the virtual models. To effectively utilize the 3D models obtained by scanning, we need to associate them with other information that is not geometrical. By associating them with other data and using them as indexes to data, we can display a greater variety of information to viewers at once. For example, when researchers are viewing a 3D model of a monument for restoration, they often want to know the names, functions, levels of damage, and progress of restoration of each part of the object. The 3D models with optional information enable them to easily access such information and use it to design the plan of restoration. There are applications that allow users to embed and view information for sparse 3D models made by modelling tools like CAD. On the other hand, applications for dense models obtained by scanning do not allow these options because it is difficult to efficiently edit and visualize large and complex models

To supply this need, in this paper, we aim to implement a GUI-based application tool which allows users to embed and view information for large models obtained by scanning. While associating data regarding objects of cultural heritage, including 3D models, with a database has been done in several previous research projects [4, 5], their primal goal is not indexing 3D models, but electronic management of information of many objects of cultural heritage. Our

approach appears similar to Geographic Information Systems (GIS) [6] in that both systems map information to geometrical models. One of our ultimate goals is to implement a system like 3D GIS on complex 3D models. However, the maps used for 3D GIS are based on one plane earth, and the methodology of 3D GIS cannot directly apply to complex 3D models. Callieri et al. proposed the system [7] that visualizes a variety of scientific information with 3D graphics of cultural heritage objects. The results of visualization using the system are very sophisticated, but the ways of mapping information are not argued in the paper.

We describe a scheme of interface between 3D models and database systems in the remainder of this paper. In Section2, we overview the system. In Section3, we describe the method of selecting mapped regions using surface segmentation. Section4 describes a demonstration using the model of Mercede church in Panama City. Section5 concludes this paper and provides the future directions.

2. Framework

We build 3D database systems in the following three steps. First, we need to build a database for storage of information regarding cultural objects. Second, we must get 3D models of cultural objects. Finally, we implement the interface between the database and 3D models. In this section, we describe the framework of our proposed 3D database system.

2.1. Building Database for Cultural Heritage Objects

Cultural heritage objects have many kinds of information that include historic data such as the origin and background of the objects, academic data such as materials and architectural styles, and information about its existing status such as the condition of the deterioration, destruction, and the plan and progress of restoration. If the object is very important, the quantity of information may be massive. These data are often recorded in analog forms, drawings and documents on papers and photographs. We must digitize them and input them in a database. In addition, there are many correlations between each other, we need to add them (Relational Database Design).

Building databases for cultural objects has already been done widely. In this paper, we assume that the database for the object is complete and available.

2.2. Obtaining 3D Models of Cultural Heritage Objects

To obtain 3D models, there are two important modelling techniques; geometric modelling and photometric modelling as shown in Figure 1.

By geometric modelling we can obtain shape information of objects. This technique consists of three steps: Data-acquisition, Alignment, and Merging. In the data-acquisition step, we use several types of laser range sensor to measure a surface geometry. Each piece of range data obtained from a different viewpoint has its own coordinate system: therefore, the next alignment step becomes necessary. We use a simultaneous alignment method, developed in our laboratory. This method avoids the accumulation errors by estimating all range data simultaneously[8]. The last step is merging. All range data, which are aligned to a common coordinate system, are converted into a single surface. We employed octrees to represent a volumetric implicit-surface representation with signed distance field[9].

There are some kinds of cultural heritage with original painting at the time of construction. For such cultural objects, we need to model photometric information as well as geometric information, and to estimate relationship between geometric and photometric information in order to perform texture mapping. To achieve it, we proposed a novel texture mapping

method which estimates parameters by comparing reflectance values in range data with color images photographed by a digital camera[10].

We have used the geometric and photometric modelling techniques in our projects such as “Bayon Digital Archival Project” [1]. In this paper, we assume that the step of obtaining 3D models is also already complete, do not explain the details of obtaining methods.

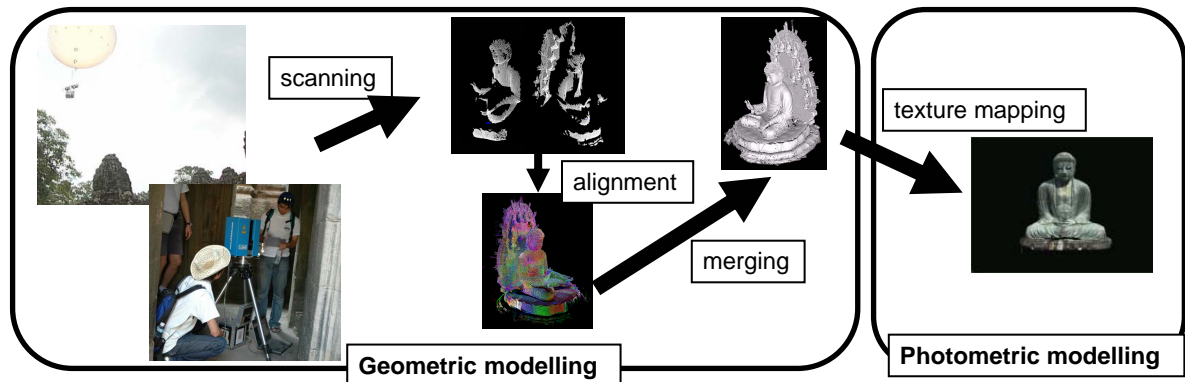


Figure 1. The process of obtaining 3D models.

2.3. Coordination of 3D Models with the Database

To realize 3D database system, we need to associate the surfaces of the 3D models with information about the objects.

We implemented a system as shown in Figure 2, in which we used 3D models as media to index. We utilized the existing database system for management of information on this system. Database can effectively deal with a variety of formats data. In addition, the database systems are specialized in procedures such as searching and rearranging data. In fact, database systems can search required records at less cost than other applications. That is why we assigned the procedures of searching and managing data to existing database systems, and implemented the interface to associate models with the information.

The process of associating a model with data on our tool is as follows:

1. Selecting a region from 3D models to be assigned data
2. Searching the record with relevant data from database systems
3. Associating the record with the selected region

The details of the procedures are described in the following sections.

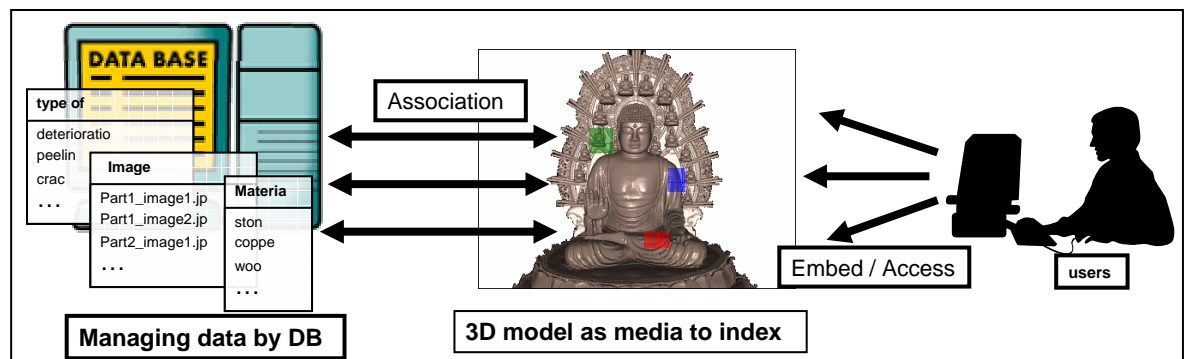


Figure 2. Using 3D models as media to index. The managing data is assigned to database systems.

2.4. Browser

After associating a model with information, viewers must be able to access to the information. To view and access the information associated with a 3D model, we need a GUI

interface, which is a browser to do them. Because the format of the information spans wide ranges, such as text, numerical value, images and links to web pages, we must implement a browser that can support all these formats. It is desirable that viewers can access information easily using the browser, and effectively evaluate the information it provides.

3. Assigning Information to 3D Models and Access Information

In the data assignment process, users first need to select a region of a 3D model to assign information to. After that, users assign information in the database to the selected region. The region selection is done by mouse strokes, as shown in Figure 3. However, it is difficult to efficiently implement this procedure for dense 3D models. To enable users to select regions efficiently, we segment the 3D model into clusters.

In this section, we explain the details of segmentation, region selection by using segmentation, assigning information from the database to 3D surfaces, and accessing information.

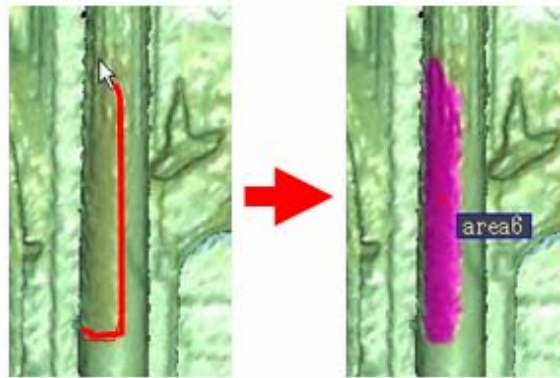


Figure 3. The operation of region selection by mouse strokes.

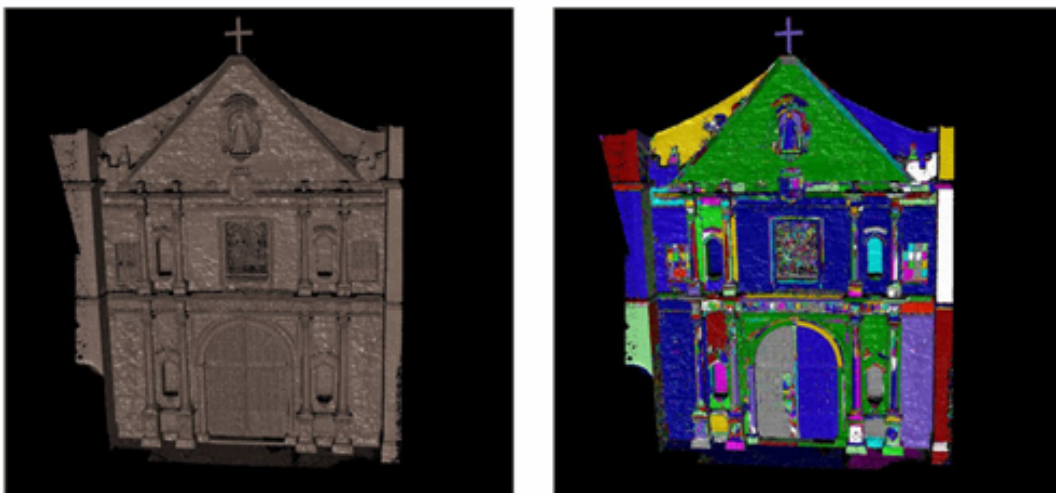


Figure 4. A segmentation image. The left image is an original 3D model. The right one is a segmented image

3.1. Segmentation of 3D Surfaces

To map the 2D region on a rendered image to the surface of a 3D model accurately shown in Figure 3, we need several procedures. First, we need to judge whether each transformed vertex is in the selected area; second, we need to determine whether each selected vertex can be visible from the viewer's position; third, we need to re-select selected vertices that belong

to one continuous segment. Implementing these procedures with accuracy is not appropriate for large 3D models, which are composed of millions of vertices and polygons. Segmentation and clustering of surfaces (see Figure 4) enables us to do the selecting procedures more efficiently and accurately. By roughly judging selected clusters we can cull the clusters that users do not expect to select clearly. To do it, we can avoid processing of many extra vertices, and save processing time. Additionally, segmentation helps users select complex regions accurately, and users can perform selecting operation more quickly.

We implemented the segmentation procedure by using a region growing algorithm. When comparing geometric or photometric parameters of one vertex next to the cluster's boundary with the average parameters of the cluster, if the difference is less than the threshold, the vertex is merged with the cluster. We used the normal and the color of each vertex as parameters in the judgement of growing. If the current cluster cannot grow, another vertex not belonging to any clusters is assigned to a new cluster, and the growing procedure restarts at the vertex.

3.2. Region Selection

Region selection is done by mouse strokes, as shown in Figure 3. In practice, by rendering the cluster image like the right image of Figure 4 on an off-screen buffer, we can more efficiently check the cluster to which the vertices to be selected belong.

In addition, users can flexibly select regions by using segmentation. It is often difficult for users to select required regions accurately, in particular when dealing with very complex models. Segmentation splits 3D models into clusters composed of vertices with similar characteristics, such as position, normal, and color. Segmentation can also split models into characteristic parts with meaningful geometric shapes or photometric colors. When users select a certain region, the region often features a specific part of the model that has geometric or photometric meaning. That means that the selected region can be often a specific cluster as shown in Figure 5. So selecting a region by cluster enables users to select it easily. That is why we implemented the mode of selecting by cluster.

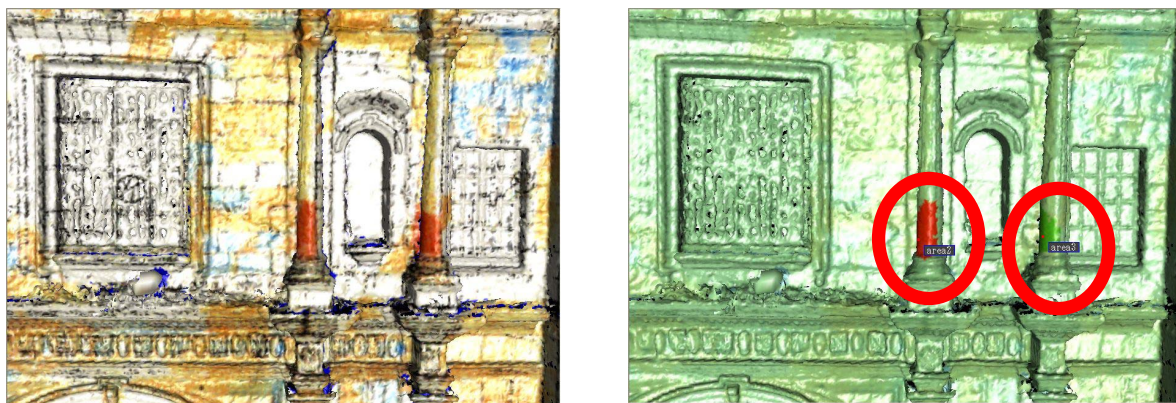


Figure 5. Region selection by cluster. The left image is a 3D model textured drawing.
The right image is the model with the region selected by clusters.

3.3. Operation of Assignment Information

After region selection, users select data, and assign it to the region. To do this, we propose an interface to take information from the database system and assign it to 3D surfaces.

The interface window is composed of text fields for selecting database sources and setup SQL statements, and a table for displaying the results of the search and selecting required records. Data sources over the network can be used in this tool. Users can rearrange the

records in the table of the result in ascending or descending order, and take records out of the table by using conditional statements.

The procedure of associating the records with the specific regions is important part of this tool because it is an intermediate operation between the database, based on text data, and 3D models that represent geometrical forms in the 3D space. We achieve this association by using drag and drop (see Figure 6). Drag and drop is an intuitive action that implies transferring objects from one place to another, and it is familiar to most computer users.

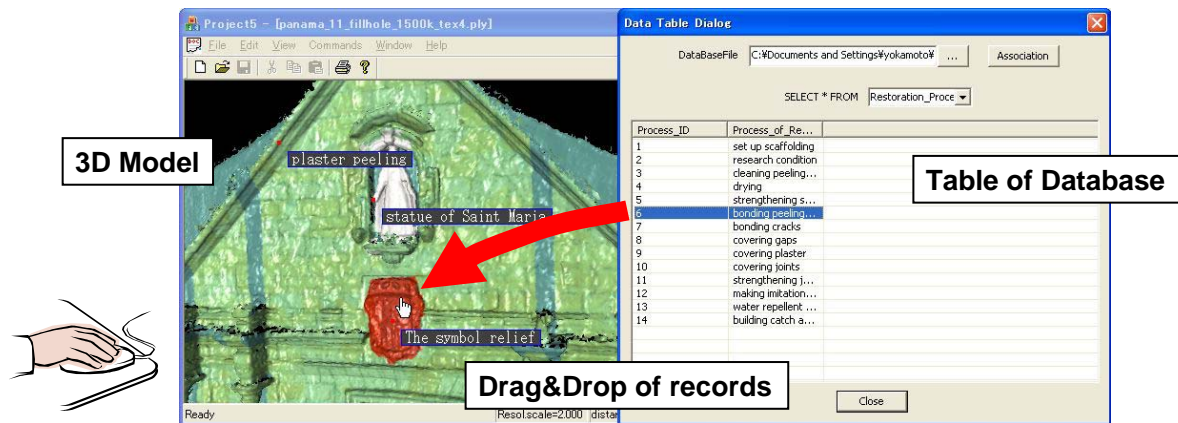


Figure 6. The operation of associating 3D surfaces with data is done by drag and drop.

3.4. Information Browser

After assigning the information to some regions, users can access it. In this stage, the 3D models are used as media to index and visualize information.

We implement the interface to view and access the information about the region. If users double-click on a region, the data assigned to the region is displayed in the window of the information browser. Users are able to view the information associated with the region, in this window text, numeric values, images, and links. The images can be easily viewed as thumbnails. Users can access and view the linked pages and execute applications by clicking the hyperlinks to web pages and thumbnails of images. Users can also reconfigure that information, and they can add and edit supplementary explanations and other data. If the database is updated, the information in the window is also updated.

4. Implementation and evaluation

In previous sections, we described how to embed information about surfaces on 3D models efficiently. In this section, we describe the overview of proposed 3D database tool, and demonstrate it by using the 3D model of Mercede Church.

4.1. Mercede Church in Panama City

Our target is to build a 3D database system of Mercede church in Casco Antiguo district, Panama City (see Figure 7).

Casco Antiguo, which is in Historic District of Panama listed in the World Heritage catalog, is a fort city developed as a Spanish settlement in the late 17th century. It has as its center a main plaza that contains historically and administratively important buildings such as Presidential Office and Cathedral. Mercede Church is also one of important buildings in Casco Antiguo. Recently, deterioration of the stone, which many of those important buildings are made of, has become apparent. To save these buildings from deterioration, activity for

restoration by researchers from Panama and Japan was initiated. In February 2002, we acquired 3D data of the church façade with the cooperation of National Research Institute for Cultural Properties (NASRIPT), Tokyo, and Instituto Nacional De Cultura (INAC). Our research group scanned the 3D shape of the church facade (see Figure 8), and built the 3D model by the methods described in 2.2. We used a Cyrax 2400 range scanner [11] to scan surfaces, and obtained 26 range images. After aligning and merging the range images, an obtained final model of Mercede Church has 1168813 vertices and 2064537 polygons.

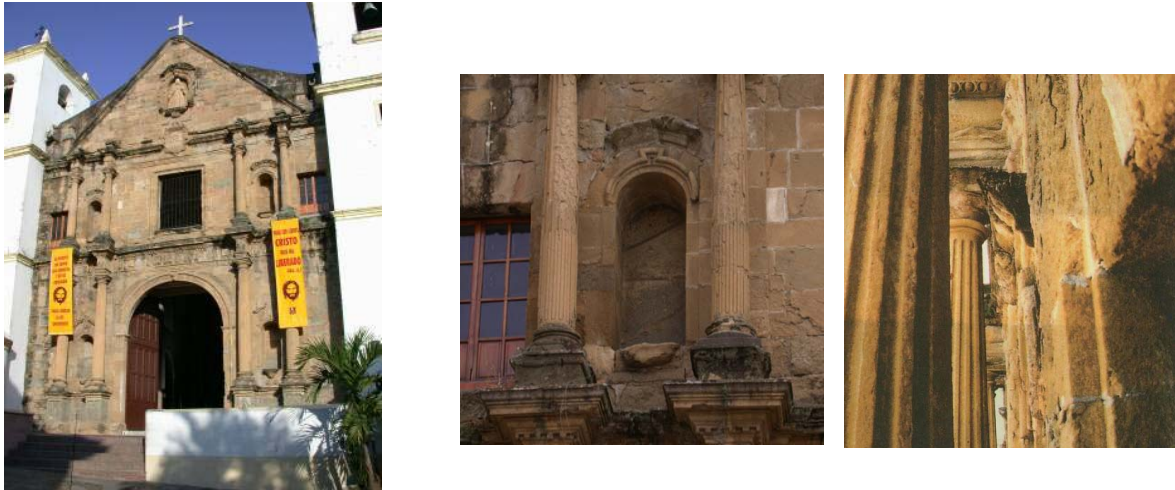


Figure 7. The two images on the left is Mercede church. The right images describe the condition of damages of Mercede church.



Figure8. Scenes of scanning by laser range scanners.

4.2. The System

We used the 3D models of Mercede Church. We performed texture-mapping of the drawing, which is describing the condition of destruction, to the model, and did segmentation by using the texture image. By using our tool, we embedded the information about damage in the 3D model. The result is showed in Figure 9. Users can view the photographs, and discover the condition of damage and restoration of progress of each region of Mercede Church by using this database on the information browser. Figure 10 shows the information browser; we configured the label, note about regions in this window. If there is a link to a web page in the associated information, users can access to the page from this window.

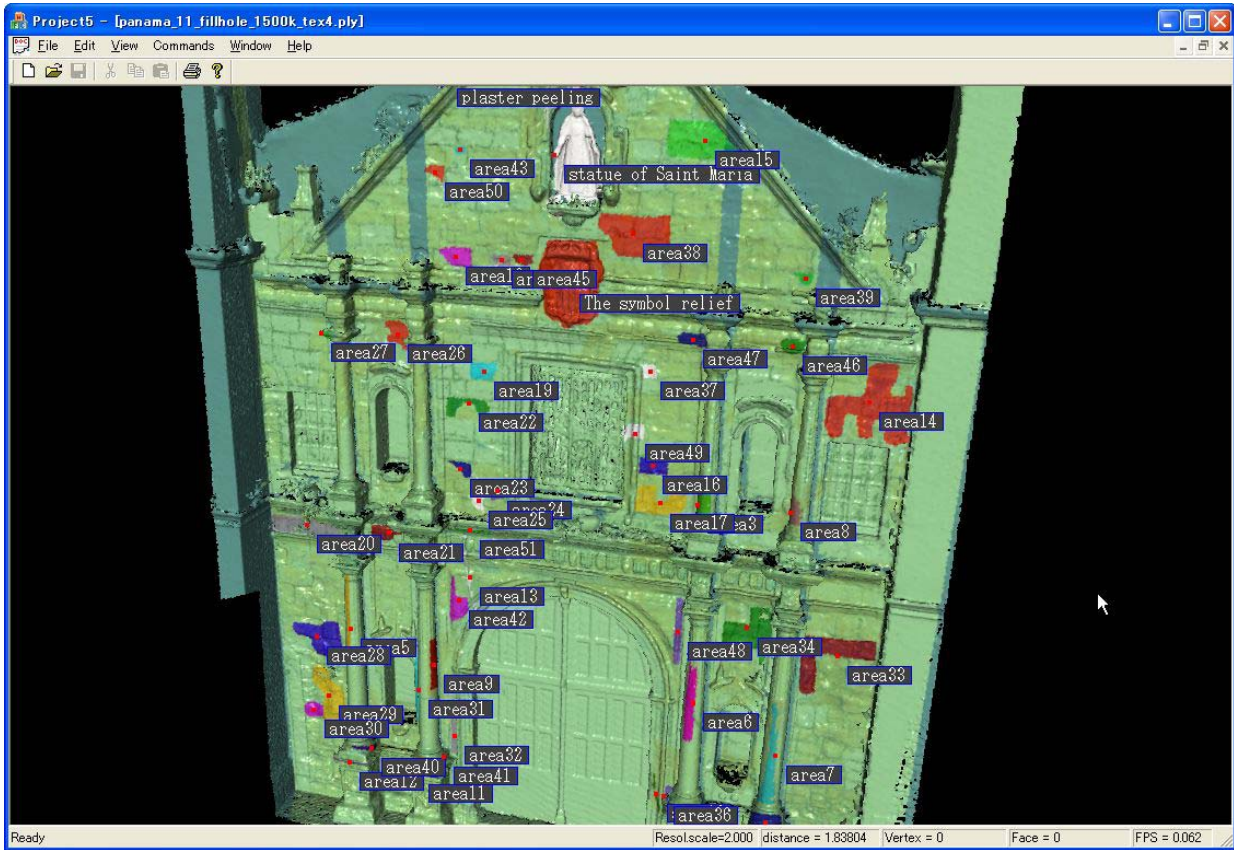


Figure 9: The 3D map of Mercede Church maps information about damages and restoration.

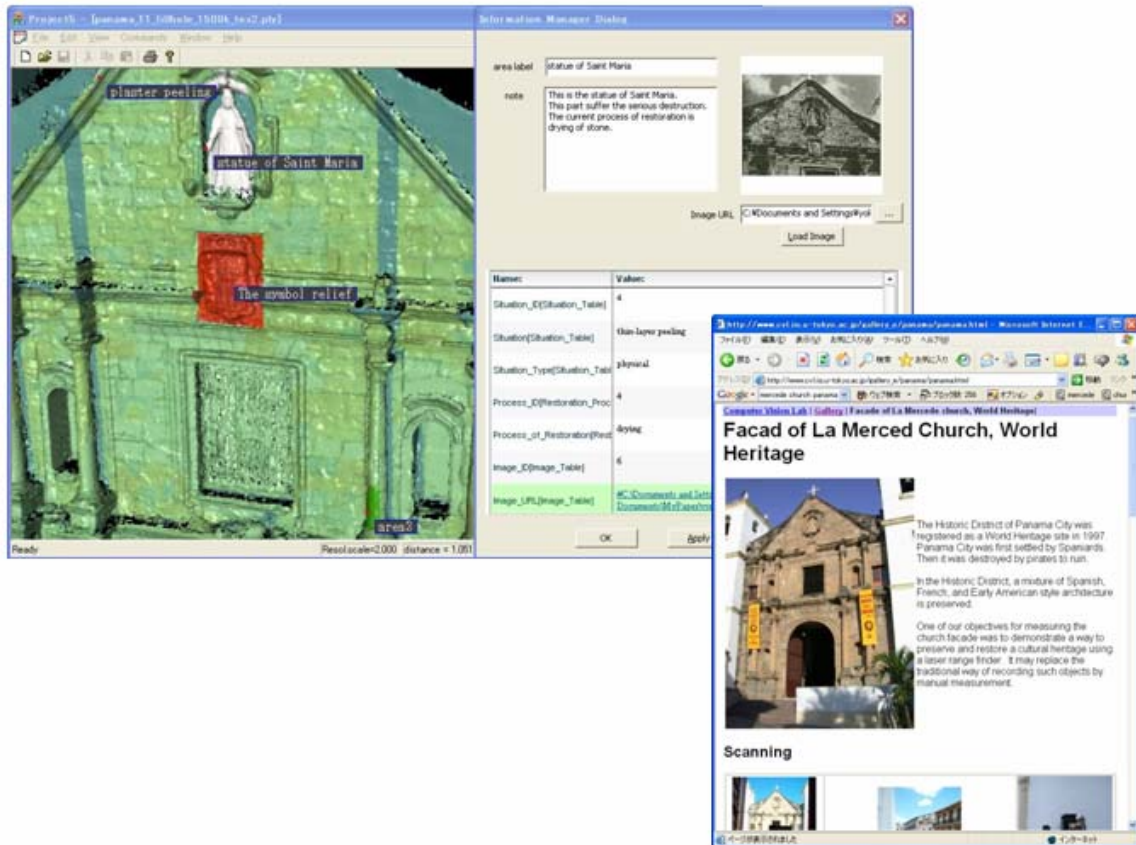


Figure 10. The information window. On this window, users can view the data table, view thumbnails of images, jump to other pages, and edit the note.

4.3. Evaluation

The cost of operation for region selection was reasonable because segmentation by using a textured image could be effectively utilized in the selection way shown in 3.2. Many regions were adequately segmented and can be easily selected by mouse clicks, which cost less than one second. However there are some regions which are not adequately segmented, in particular the parts with extremely complex shapes and vague color variations. Such regions can only be selected by enclosing them by mouse dragging, which cost between several seconds and several tens of seconds. This selecting operation by mouse dragging need much more time than selection by mouse clicks. We assigned users the task; which is selecting 40 regions which almost half of the regions are adequately segmented and the others are not adequately segmented. In the case of allowing selecting using clusters, the average selecting time was about 5 minutes, while in the case of not allowing it, it was about 10 minutes. This result shows that segmentation enable us to get performance gain in selecting regions.

The cost of the operation of embedding information to selected regions was also reasonable. The operation of embedding by using drag and drop was very easy for users. The cost of this stage depends on the formation of the database. On the current system, it takes about 20 minutes to embed information to 40 regions. In the case that users have to type all information, it must take more time. To embed information smoothly, the data on database systems must be also managed adequately. On the information browser, operations of viewing some information and accessing linked pages can be done very easy.

5. Conclusion and Future Work

In this paper, we described how we connect 3D models with a database, and efficiently deal with large 3D models using our 3D database tool. We were able to select and access regions efficiently by using segmentation of 3D surfaces, and index images. From our demonstration of Mercede Church, we verified better usability and efficiency of processing for large 3D models.

By using our proposed tool, users can embed a variety of information in 3D models and use them as media to index information. These 3D models with information can be utilized not only for the storage and display of cultural objects, but also in other fields, for example engineering, advertisement, education, and so on. The usability of this tool is suitable for those who are in the field and are not expert in computers.

There is some room for improvement in this tool. First, we have to improve the performance of selecting procedures by adopting more advanced segmentation algorithm which gives us more adequate segmentation. Second, we need to adopt more efficient rendering algorithm. In this tool, the 3D models are rendered by simple polygon rendering, and this method is not suitable for larger models composed of millions of polygons. In the future, we intend to implement a method using advanced algorithms such as point-based-rendering [12] or other efficient rendering methods like Adaptive TetraPuzzles [13], and extend the rendering system to a network version that users can use with any models if they are online.

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