Development of 3-D Contents Management System for Digital Archives

Tetsuo Shoji,[†] Yoshihiro Okada,[†] Kogi Kudara,[††]
Takashi Irisawa[†††] and Yoshihisa Oda[††]

In an archaeology field, it is necessary to treat 3-D computer graphics including images, documents, plans and measurement data for ruins or remains. In this paper, we generate 3-D model from Kizil Caves, and contents of Otani Mission images. Then, we develop a management system of these contents by using XML. Our approach consists of the followings steps: First, we reconstruct 3-D model of Kizil Caves from the orthographical views based on volumetric intersection method. Secondly, we describe a method of mapping real images onto the reconstructed 3-D model,and we attache indexes of Kizil Caves. Thirdly, in Otani Mission images, we digitized dry plates and films, and attache indexes of these images. Then, in order to manage these contents, we develop a 3-D and 2-D contents management system with XML. Finally, we have confirmed its effectiveness for our system, experimentally.

1. Introduction

In recent years, application of 3-D computer graphics(CG) has been widely researched. Virtual reality archeology[1)] is one of these application, and this is a new field that combines an archeology and computer graphics to reconstruct archeological site. In an archaeology field, it is necessary to treat 3-D computer graphics including images, documents, plans and measurement data for ruins or remains. The purpose of this paper is to generate 3-D model for ruins, to manage various data, we develop 3-D and 2-D contents management system about Kizil Cave Temple and Otani Mission. The Kizil Cave Temple shown in Fig.1 is located at the northern bank of Muzart River. It has 236 caves which have been numbered, including three kinds of caves:the monks' living quarters and those for worshiping and other religious activities. In order to research the Kizil Cave Temple, many foreign expedition visited to Kizil. For example, there were T.Watanabe and K.Hori who belongs to the Otani Mission in 1903, and A.Grunwedel who belongs to the German expedition in 1906.

Fig. 1 Kizil Cave Temple in 2001

The Otani Mission, which was directed by Kozui Otani(1876-1948), the twenty-second abbot of Nishi-Hongwanji, brought back many precious materials from Central Asia. This collection consists of 9,000 items which include ancient handwritten Buddhist sutras discovered at Tun-huang, socio-economic records, literature written in Central Asian languages, botanical specimens, dyed and woven goods, and an outfit, a diary, and photos of the party members.

In Section 2, we describe a method of reconstructing 3-D model of Kizil Caves from the orthographical views, and texture mapping onto 3-D model,and indexing 3-D model of Kizil Caves. Section 3 describes about indexing Otani Mission images. Section 4 presents constructing contents management system with XML.

2. Generation of 3-D Contents for Kizil Caves

In this section, we explain a method of recon-

† Ryukoku University Science and Technology
†† Ryukoku University Faculty of Letters
††† Ryukoku University Faculty of Business Administration
Tetsuo Shoji
Ryukoku University School of Science and Technology, Seta Oe-Cho Yokotani,Ostu, Shiga, 520–2194
Phone: +81–77–543–7418
Fax: +81–77–543–7428
E-mail: shoji@mail433.elec.ryukoku.ac.jp

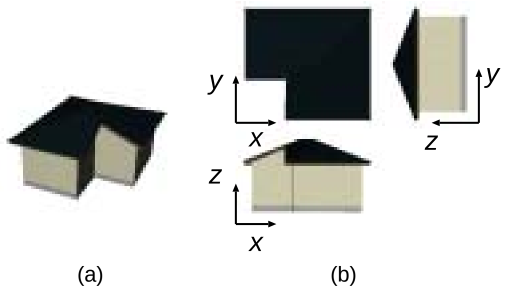

Fig. 2 The orthographical views made with CG tool

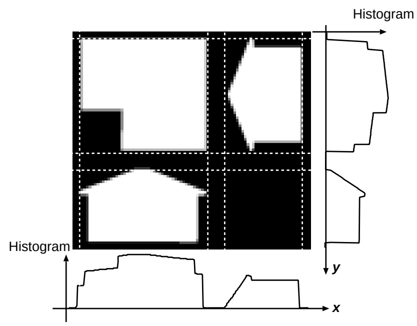

Fig. 3 Division of the orthographical views

structing 3-D model of Kizil Caves. In order to reconstruct 3-D model of Kizil caves, we use orthographical views of kizil Caves shown in the reference[2).

In previous works, there are many methods[3)4)5) for reconstructing 3-D model from orthographical views or floor plan with 2-D CAD. In the conventional method, vertices and edges information of these views are used. However, we are not able to reconstruct 3-D model by applying these method to the orthographical views, because we use these views that are rough sketches of ancient structure and ruin. Our approach consists of the following steps:

(1) Preprocessing
(2) 3-D modeling from orthographical views
(3) Texture mapping onto 3-D model
(4) Indexing for 3-D model

The details of these steps are described below.

2.1 3-D modeling of Kizil Caves

2.1.1 Preprocessing

As preprocessing to reconstruct 3-D model, we remove noise for the orthographical views. Then, it is necessary to divide the orthographical views into front, side, top view, because of reconstructing 3-D model.

Using Fig.2, we describe a method of the division of the orthographical views. Fig.2 (a) shows the 3-D model made with Computer Graphics tool, and Fig.2 (b) shows the orthographical views generated from this 3-D model. Our approach consists of the following steps:

(1) The histogram of white pixels is generated from the orthographical views for x-axis and y-axis direction,respectively.
(2) The orthographical views is divided into the front, side, top based on the lowest points of the histogram,respectively,as shown in Fig.3.

2.1.2 Reconstruction of 3-D model of Kizil Caves

In order to reconstruct 3-D model of Kizil Caves from the orthographical views, we apply a method of volumetric intersection[6) to these views. This method is to reconstruct 3-D model based on silhouettes of an object from multiple views.

For the orthographical views which consist of a front view, a side view and a top view, reconstruction of 3-D model is performed as follows:

(1) Voxel space is defined as group of voxel(Fig.4(a)).
(2) Each voxel is conversely projected onto the front, side, and top view by using orthographical projection model. Then, we decide whether the voxel exists on three views. If the voxel doesn't exist on these views, the voxel is deleted from voxel space(Fig.4(b)).
(3) The group of voxel existing finally in voxel space is 3-D model(Fig.4(c)).
(4) Finally, in order to map a real image onto reconstructed 3-D model, we delete inner voxels from this model.

We reconstruct 3-D model based on the above method from the orhographical views shown in Fig.2 (b). Reconstructed 3-D model is shown in Fig.5, and we evaluate reconstructed 3-D model by comparing 3-D model shown in Fig.5 with the original 3-D model shown in Fig.2 (a).

As a result, the average of the error with side length was 1.63%. Therefore, it was confirmed that above method was effective for the orthographical views.

Then, we generate silhouettes from the orthographical views of Kizil Caves shown in Fig.6(a)(c). Next, we reconstruct 3-D model of Kizil Caves based on above method. The reconstructed 3-D model are shown in Fig.6(b)(d).

2.2 Texture mapping for reconstructed 3-D model

In this section, we describe about a method to

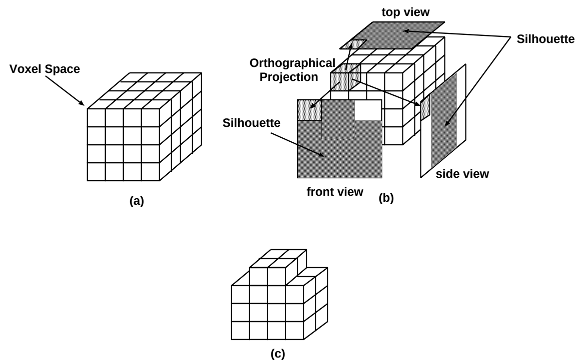

Fig. 4 The method of volumetric intersection: (a) Voxel Space with voxel (b) Orthographical projection voxel onto front, side, top view, (c) Reconstructed 3-D model

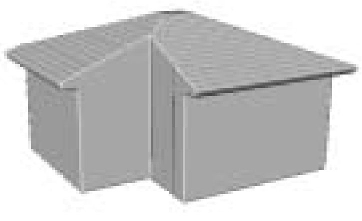

Fig. 5 Result of 3-D model

map a real image onto 3-D model reconstructed from the orthographical views. Generally, in order to map real images onto 3-D model, it is necessary to obtain accurate 3-D model and to know camera parameters of images[7)~10)].

However, in this work , it is difficult to map a real image onto 3-D model which are reconstructed from the orhographical views, because we use those views drawn with free hand, and, reconstructed 3-D model are not accurate, we use a real image which is unknown camera parameters. Therefore, texture mapping onto this reconstructed 3-D model is performed as following steps:

(1) Projection of 3-D model onto 2-D plane
(2) Comparison of a real image and projected 3-D model
(3) Correction of 3-D model based on interactive processing
(4) Correspondence between points of 2-D and 3-D coordinates
(5) Texture mapping onto 3-D model

The details of these steps are described below.

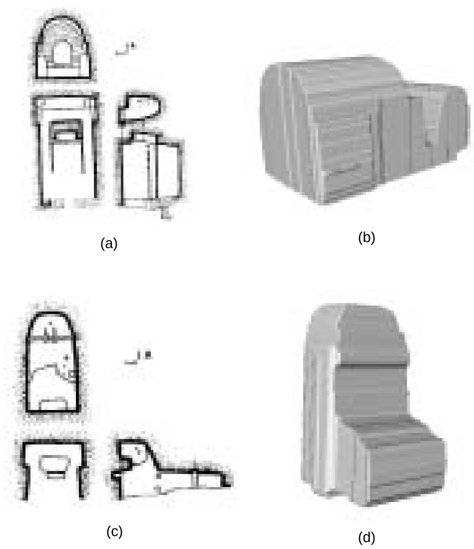

Fig. 6 Reconstructed 3-D model of Kizil Caves: (a) The orthographical views of Kizil No.8 cave, (b) 3-D model reconstructed from (a), (d)The orthographical views of Kizil No.139 cave, (e)3-D model reconstructed from (d)

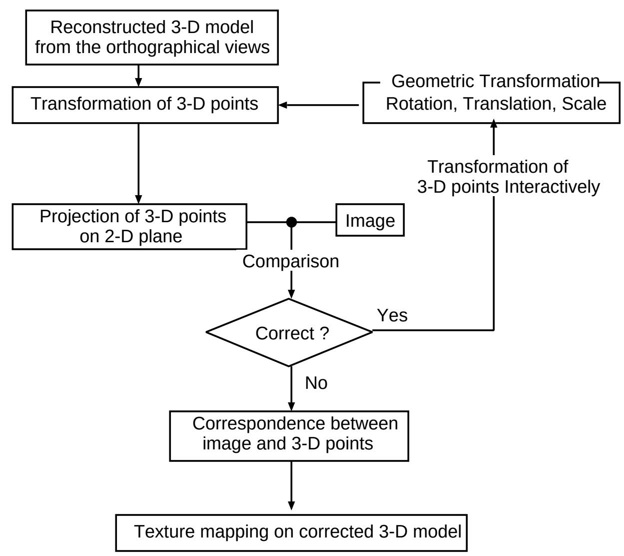

Fig. 7 Texture mapping based on interactive processing

2.2.1 Texture mapping based on interactive processing

(1) Setup perspective projection
Assuming that the real image is perspective projection, we use camera model of perspective projection for reconstructed 3-D model. We use "gluPerspective function" which is function of the OpenGL

for perspective projection transformation. The OpenGL is a software interface to graphics hardware, and "gluPerspective" is a function to project 3-D model onto 2-D plane by using perspective projection model.

(2) Setup camera position and direction
We use a real image with unknown camera parameters. Therefore it is difficult to estimate camera position and direction from a real image. In this paper, we perform geometric transformation of 3-D model interactively and shape matching between a real image and transformed 3-D model. The geometric transformation are described below.

$$\begin{bmatrix} X' \\ Y' \\ Z' \\ 1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \quad (1)$$

Translation matrix T is shown as:

$$T = \begin{bmatrix} 1 & 0 & 0 & x \\ 0 & 1 & 0 & y \\ 0 & 0 & 1 & z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

Scale matrix S is shown as:

$$S = \begin{bmatrix} x & 0 & 0 & 0 \\ 0 & y & 0 & 0 \\ 0 & 0 & z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

Furthermore, rotation matrix R is shown as:

$$R_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & cos\theta & -sin\theta & 0 \\ 0 & sin\theta & cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

$$R_y = \begin{bmatrix} cos\theta & 0 & sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -sin\theta & 0 & cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

$$R_z = \begin{bmatrix} cos\theta & -sin\theta & 0 & 0 \\ sin\theta & cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (6)$$

where R_x is a matrix for rotation about x axis, and R_y is a matrix about y axis, R_z is a matrix about z axis.

(3) Adjustment of 3-D model
We perform very little adjustment of transformed 3-D model interactively after processing of shape matching.

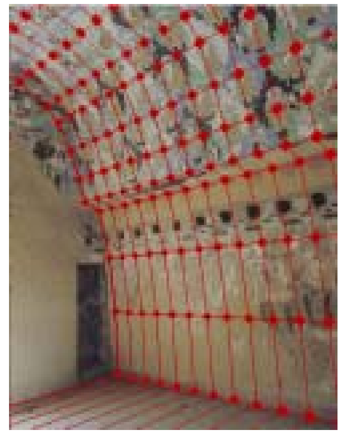

Fig. 8 Corrected 3-D model based on interactive processing

Using the above method, the corrected 3-D model is shown in Fig.8. In this figure, corrected 3-D model is represented by wireframe model.

2.2.2 Correspondence between points of 2-D and 3-D coordinates

In order to map the real image onto corrected 3-D model, it is necessary to acquire correspondence between the 3-D coordinates of corrected 3-D model and 2-D coordinates of the real image. In this paper, we use the projection matrix to acquire correspondence of them. The projection matrix **P** is shown as:

$$\boldsymbol{P} = \begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \end{bmatrix} = \begin{bmatrix} \boldsymbol{P}_1^T & p_{14} \\ \boldsymbol{P}_2^T & p_{24} \\ \boldsymbol{P}_3^T & p_{34} \end{bmatrix} \quad (7)$$

Correspondence between points 2-D and 3-D coordinates is determined by

$$s\boldsymbol{m} = \boldsymbol{PM} \quad (8)$$

with

$$\boldsymbol{m} = [u, v, 1]^T, \boldsymbol{M} = [X, Y, Z, 1]^T \quad (9)$$

where **M** is 3-D coordinates (X, Y, Z) of 3-D model, and **m** is 2-D coordinates (u, v) of a real image, s is scaling factor. Then, projection matrix **P** is performed by solving the evaluation function shown as:

Fig. 9 Result of texture mapping for kizil Cave

$$C = \sum_{i=1}^{N}(\frac{p_1^T M_i + p_{14}}{p_3^T M_i + p_{34}} - u_i)^2 + \sum_{i=1}^{N}(\frac{p_2^T M_i + p_{24}}{p_3^T M_i + p_{34}} - v_i)^2 \qquad (10)$$

The result of texture mapping for Kizil Cave is shown in Fig.9. However, there are the area of non texture in this figure. The main reason is that there are not real image corresponding to these area.

2.3 Indexing for 3-D model of Kizil Caves

In order to manage 3-D model of Kizil Caves, we attache indexes data obtained from reference[2)], These indexes data consist of period, position, cave number,type of shape, file name of the orthographical views, and file name of 3-D model. For example, the 3-D model of Kizil shown in Fig.6 (a) has indexes below.

- cave number: 8
- position: Valley West
- period: The 7th century
- type of shape: Center Pillar Cave
- image: kizil-image/8.jpg
- 3-D model: 3-dmodel/8.wrl

3. Indexing for Otani Mission images

In this section, we explain a method of indexing Otani Mission images. In Ryukoku university, there are many films and dry plates for Otani Mission, at present. These films and dry plates were taken by Otani Mission from 1903 to 1914. These provide us with important information which were situation of ruins and remains in 1903.

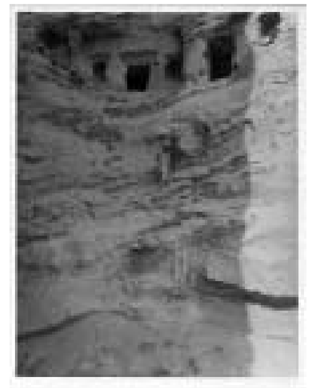

Fig. 10 Dry plate(Kizil Caves) taken in 1903

First, we digitize these films and dry plates, because these films and dry plates are easy to break.

Then, in order to manage these digitized films and dry plates, we attache indexes data. These data consist of date, caption, original plate(dry plate or film), file name of image. For example, Fig.10 shows dry plate taken in 1903, and the indexes of this dry plate is below.

- Date: 1903/April
- Caption: Climbing up to the Caves by Alpine rope in E.C Minui near Kizil
- Origin plate: dry plate
- image: otani-image/kizil-1.jpg

4. Management of 2-D and 3-D contents

In this section, we explain a method of managing contents which are Otani Mission images and 3-D model of Kizil Caves. In order to manage contents, we apply XML(eXtensible Markup Language) to indexed data of Otani Mission images and 3-D model of Kizil Caves.

XML provides an ideal mechanism for defining the structure of archived contents. Its functionality is inherited from SGML, simplified for Internet applications. Whereas HTML tags describe presentation, XML tags define contents and data structures.

Outline of management system shows in Fig.11 and this development environment shows in Table.1. This system is as follows.

First, we generate XML data by using index-

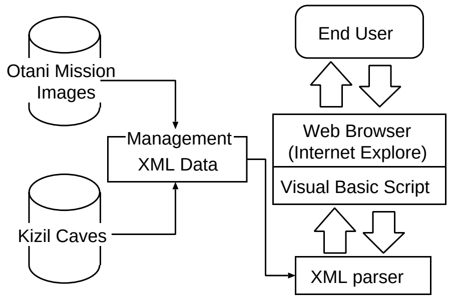

Fig. 11 Management System

ing data of Kizil Caves and Otani Mission images. Fig.12 shows the XML data for one of the contents.

Then, we extract required data from XML data by using query form on Web browser. Fig.13 shows query form which consists of Otani Mission images and Kizil Caves. End user can retrieve Otani Mission images by using date, keyword, and plate as queries, and retrieve Kizil Caves by using position, period, and shape type as queries.

Finally, the retrieval result are represented after transforming retrieved data from XML data to HTML data by using XSLT (eXtensible Stylesheet Language Transformations).

Fig.14 shows result retrieved by using keyword of “kizil” as a query, in Otani Mission images. Table 2 shows result retrieved by using keyword and Table 3 shows result retrieved by using plate. Then, Fig.15 shows result retrieved by using shape type of “Rectangle Cave” as a query, in Kizil Caves. Table 4 shows result retrieved by using shape type of these caves, and Table 5 shows result retrieved by using position of these caves.

Table 1 Development environment

CPU	PentiumIII Xeon 1.0GHz
Memory	512MB
OS	Windows2000
XML parser	msxml3.0
3-D model	VRML1.0
Development	VisualC++ 6.0 OpenGL, VBScript

Table 2 Retrieval result for keyword of Otani Mission images

keyword	Hits/all
Kizil	32/436
Kumutra	6/436
East Hastam	18/436
West Hastam	10/436


```
<?xml version=”1.0” encoding=”UTF-8” ?>
<contents>
    <otani_img>
        <No CanNo=”1(1)” PaperNo=”174”>
        <keyword>W-Hasatam</keyword>
        <image>image01-1_1-5.jpg</image>
        <date>1903/July</date>
        <caption>Large decayed Stupa in
        W. Hasatam</caption>
        <photo_number>-</photo_number>
        <publication>publication</publication>
        <plate>dry plate</plate>
        <person>-</person>
        </No>
    </otani_img>
    <kizil>
        <cave>
        <no>1</no>
        <position>Valley West</position>
        <period>-</period>
        <type>Rectangle Cave</type>
        <image>caveimg/1.jpg</image>
        <cave3d>cave3d/1.wrl</cave3d>
        </cave>
    </kizil>
</contents>
```


Fig. 12 An example of XML data for Otani Mission images and Kizil caves

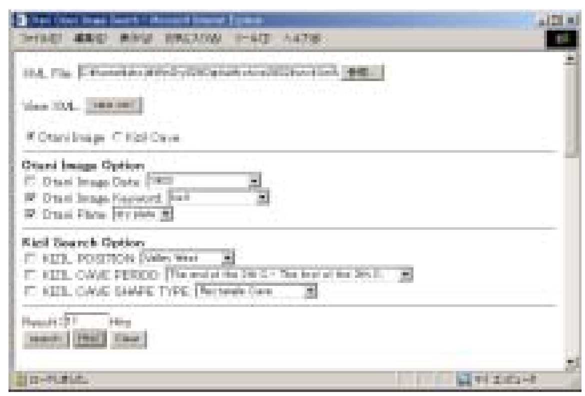

Fig. 13 Query form

5. Summary

In this paper, we develop a 3-D contents management system for Kizil Caves and Otani Mission images. First, in Kizil Caves, we explain a method of reconstructing 3-D model from the orthographical views. Then, we describe about a method of texture mapping onto 3-D model,

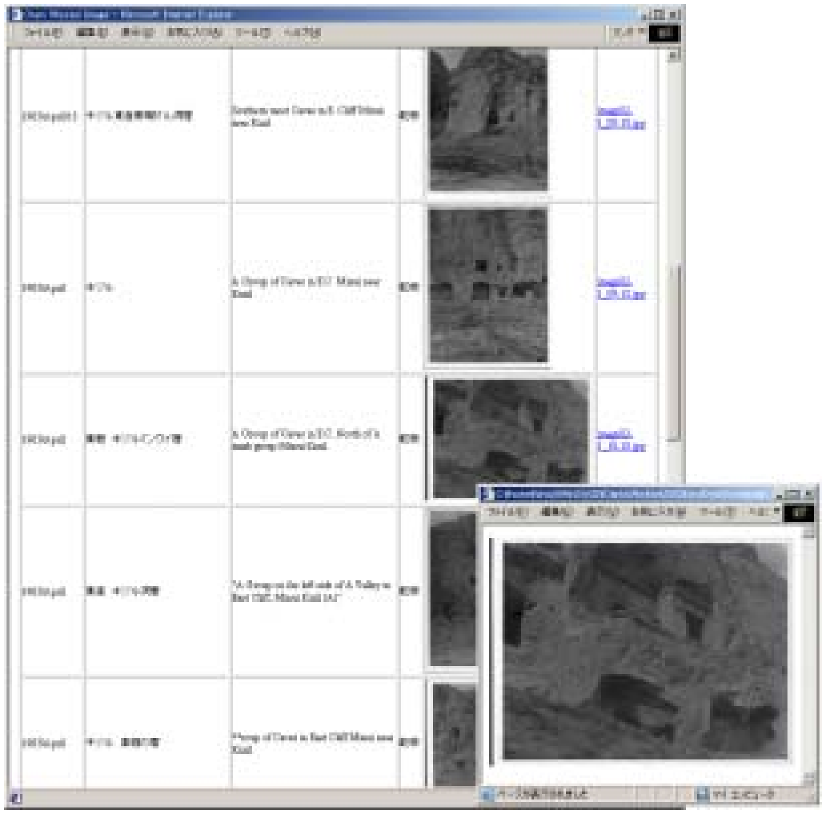

Fig. 14 Retrieval result for Otani Mission images

and attached indexes for 3-D models. Secondly, in Otani Mission images, we digitized dry plates and films and attached indexes for them. Then, in order to manage these contents, we developed a 3-D contents management system with XML. Finally, we have confirmed its effectiveness for our system, experimentally.

In future works, it is necessary to analyze images, and extract feature of shape or structure from images, and manage contents including these feature.

Table 3 Retrieval result for plate of Otani Mission images

plate	Hits/all
film	74/436
dry plate	288/436

Table 4 Retrieval result for shape type of Kizil Caves

shape type	Hits/all
Monk's Living Cave	59/236
Rectangle Cave	83/236
Center Pillar Cave	61/236

Table 5 Retrieval result for position of Kizil Caves

position	Hits/all
Valley West	135/236
Valley East	71/236
Mountain South	20/236
Mountain North	10/236

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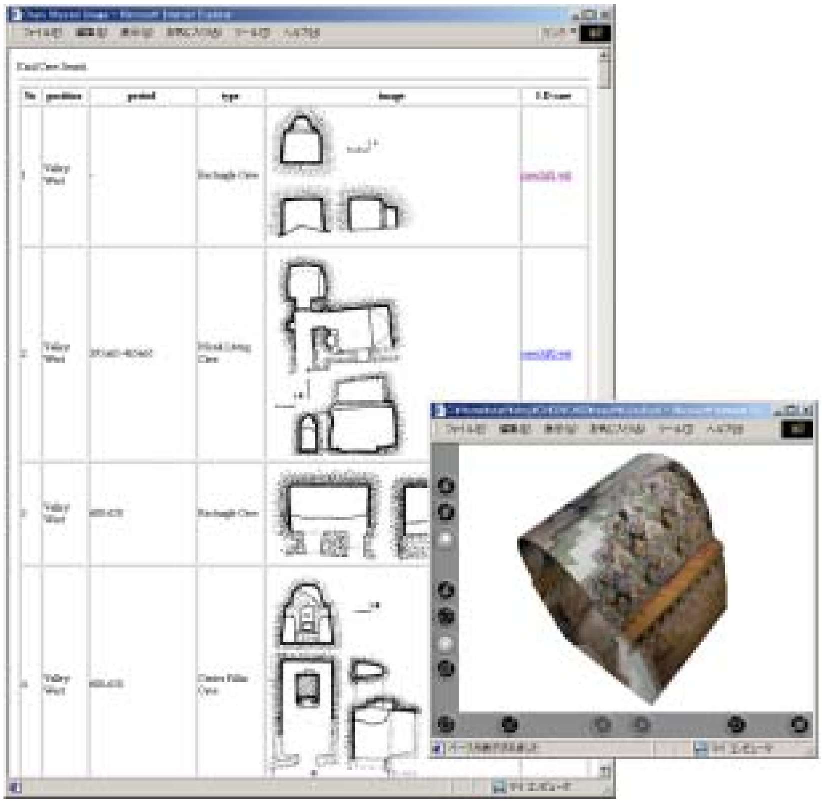

Fig. 15 Retrieval result for Kizil Caves

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